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Positive Energy

CARBON CAPTURE, UTILIZATION AND STORAGE

POLARIZATION, PUBLIC CONFIDENCE AND DECISION-MAKING

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EXECUTIVE SUMMARY

Canada has developed extensive expertise and experience in carbon capture, utilization and storage (CCUS). The country's four large-scale integrated projects include carbon dioxide (CO_2) capture at a coal-fired electricity generating facility, upstream oil production facilities, and a fertilizer plant. Depending on the project, CO_2 injection and storage occurs as sequestration in a deep saline aquifer geologic formation (CCS) or for enhanced oil recovery (EOR) operations.

Alongside carbon capture and sequestration, carbon transformation and conversion, also under the umbrella of CCUS, are among the only options for point-source emissions-intensive and trade-exposed industries (EITE) such as cement, steel, and chemical manufacturing. In the last fifteen years, the CCUS industry has emerged as an important option for EITE reductions and emissions reductions more broadly, but it has not reached its potential.

Despite Canadian expertise, and the fact that CCUS forms part of emissions reduction scenarios, the technology faces challenges across a range of mostly socio-economic and political risk issues. This includes concerns for the adequacy of regulatory oversight and polarization over carbon issues more broadly. Technologies such as CCUS that extend or continue fossil fuel operations can be polarizing because of concerns over the degree of actual carbon reductions that occur with their use compared to renewable energies. They can also be polarizing technologies when it comes to local community social acceptance and trust, the pace of development of the industry, and cost concerns.

Thus, this study, which is part of Positive Energy's broader research stream on polarization (see Box 1), examines the following question:

> *What are the key risk issues driving polarization and public confidence over CCUS and government decision-making processes that govern and support it, and how might they be addressed?*

The study undertook a comprehensive review of academic, industry, and government publications, and in-depth interviews with decision-makers from a variety of different sectors related to CCUS policy and implementation. Interviewees included senior leaders from the federal government, research and funding institutions, the private sector (fossil and trade-exposed industries, both as technology developers and users), and non-government environmental and carbon capture advocacy organizations.

The research began by exploring whether CCS, CCUS and carbon conversion are considered 'clean tech' in Canada. This speaks to whether stakeholders and governments in Canada view this set of technologies as part of the country's climate change mitigation efforts. Findings suggest that with a few caveats, these technologies are seen to meet criteria for clean tech. This is important because although 'labels' may not address the climate change imperative, current funding programs and government policy directions are geared to being 'clean.' Consideration of CCUS as 'clean' is therefore crucial for further development and deployment of the technology.

With respect to the risk issues related to public confidence, participant responses were categorized into thirteen categories. Approximately half are issues that can be addressed by multiple stakeholders, while others require specific leadership from government or industry. The issues emerging as the highest concern include:

- How to achieve tolerable costs
- Incomplete knowledge and inadequate information provision
- Industry pace of innovation and demonstration
- Perceptions of other mitigation alternatives
- Fairness with respect to the distribution of costs and benefits of CCUS

While all of the risk issues relate to public confidence challenges, only a small subset emerges as potentially polarizing (i.e., situations where opinions are split into disparate extremes, with little middle ground). For instance, social acceptance of CCUS technologies is vulnerable to polarized debates given the high capture costs, prevalence of EOR projects, which tend to be more controversial than other aspects of CCUS, and related concerns for projects or government research and development investments that may increase or extend fossil fuel use.

Other risks are not necessarily polarizing per se, but strongly affect public confidence in CCUS implementation more broadly. An example is whether or not there are transparent, engaged, and accountable decision processes, including robust regulatory oversight.

Participants also suggested risk management options to address polarization and public confidence concerning CCUS and regulatory frameworks. Recommendations for action are under the purview of government or industry, often working in concert.

The study identifies eleven recommendations, grouped into five categories[1] (see Discussion and Recommendations for Action for greater detail):

Policy/Regulatory Measures

1. Develop a national vision for CCUS in the context of Canadian climate policy

2. Develop stable, detailed and coherent climate policy that provides motivation for CCUS development (notably carbon pricing)

3. Increase federal-provincial policy collaboration to foster policy stability and reduce risk

Economic/Financial Measures

4. Use carbon pricing to provide economic incentives for CCUS

5. Use cost-sharing between government and industry to help move the technology forward, while still providing incentives for efficient and successful technology development that reduces the risks of full subsidization

1. We use a lightly modified version of the REACT framework for risk management and population health (Krewski et al., 2007) as the basis of this categorization (see Discussion and Recommendations for Action).

Advisory/Communications Measures

6. Improve analysis, research, and communication of CCUS from broader perspectives such as lifecycle analysis, or by inclusion of multiple factors (e.g., job creation)

7. Improve wide-ranging communication and understanding of CCUS technologies, their approaches and uses, across energy systems and industrial contexts

8. Ensure effective communication of cost improvements in the technology to policymakers, stakeholders, and the public

9. Increase knowledge-sharing and demonstrations in international export markets to increase opportunities for Canadian leadership

Community-based Measures

10. Perhaps most importantly, use transparent engagement processes in all activities to build support and trust between and among stakeholders and industry

Technological Measures

11. Extend the development and communication of CCUS to focus on all potential applications and storage options, notably for 'hard to reach' sectors like emissions-intensive and trade-exposed industries.

This study suggests that a wide variety of actions are needed in order for CCUS to make the contribution to climate mitigation that continues to be envisioned for large industrial sites.

This is particularly important in the context of the COVID-19 pandemic, which has created unprecedented health and economic impacts. Economic and fiscal uncertainty will impact the future of CCUS in the near and medium term. In fall 2020, the federal government made a broad range of climate commitments, including net zero by 2050 legislation, a climate plan that commits to ramping up the carbon tax to $170 per tonne by 2030, and a national hydrogen strategy. Ottawa also stated that the path to net zero includes the oil and gas sector and made a $100 million investment to help reduce the sector's environmental impact, including emissions reductions.

All of this helps set the stage for increased CCUS development and implementation. However, adequate capital for technology development and deployment remains a serious concern, as does the need for action on the full suite of recommendations above. If government emphasis on climate mitigation continues throughout the recovery period, this could represent a fruitful opportunity for Canada to take action on all of these fronts at the domestic and international levels.

BOX 1: POSITIVE ENERGY'S RESEARCH ON POLARIZATION

The second three-year phase of Positive Energy (2019-2021) aims to address the following question: How can Canada, an energy-intensive federal democracy with a large resource base, build and maintain public confidence in public authorities (federal, provincial, and territorial policymakers and regulators, Indigenous governments, municipal governments and the courts) making decisions about the country's energy future in an age of climate change?

Three fundamental questions form the research and engagement agenda. How can Canada effectively navigate and overcome polarization over its energy future? What are the respective roles and responsibilities of policymakers, regulators, the courts, municipalities and Indigenous governments when it comes to decision-making about the country's energy future? What are the models of and limits to consensus-building on energy decisions?

Understanding the various dimensions of polarization over energy and environmental issues is fundamental to addressing roles and responsibilities, as well as models of and limits to consensus-building. Positive Energy's research and engagement on polarization seeks to understand polarization as a general phenomenon affecting policies of all sorts, to assess the nature and extent of polarization when it comes to energy and environment, and to offer strategies to address or navigate polarized contexts.

The polarization research programme includes the following projects:

- A literature review on polarization as a general phenomenon: its causes, severity and consequences
- Original survey research to measure and track polarization among decision-makers and the general public
- Interviews with energy and environmental leaders to understand the role of language and terminology: unpacking assumptions and interpretations of the term "transition"
- Exploring attitudes and the role of values when it comes to perceptions of energy technologies (renewable energy technologies and carbon capture, utilization and storage)
- Identifying "What Works?": case studies of organizations and programs designed to address polarization

These studies are available on the Positive Energy website.

GLOSSARY

Organizations and project types

Bioenergy with carbon capture and storage (BECCS) – burning biomass as a fuel source (trees or crops), with capture, injection and permanent storage of CO_2 emissions

Carbon Sequestration Leadership Forum – a ministerial-level international climate change initiative focused on the development of improved cost-effective technologies for CCS

Clean Energy Ministerial – a partnership of the world's key economies working together to accelerate a global clean energy transition

CO_2 point-source capture – a generic term for approaches that capture CO_2 from the combustion of fossil fuels at large emission sites

Direct air capture – a technology that captures carbon dioxide directly from the ambient air as opposed to an industrial point-source of emissions

Emissions-intensive and trade-exposed (EITE) industries – heavy manufacturing industries such as refined petroleum products, iron and steel, cement, aluminium, chemicals, fertilizer, and pulp and paper, that are both greenhouse gas emissions-intensive and trade into international markets; they are therefore sensitive to international competitiveness concerns when emissions reductions measures add high costs to their operations

Enhanced oil recovery (EOR) – the process of recovering oil from an almost depleted reservoir, usually by injecting a substance into an existing oil well to increase pressure and reduce the viscosity of the oil

Large-scale integrated projects (LSIPs) – projects involving the capture, transport, and storage of CO_2 at a scale of at least 800,000 tonnes of CO_2 annually for a coal-based power plant, or at least 400,000 tonnes of CO_2 annually for other emissions-intensive industrial facilities such as upstream oil and gas, or natural gas-based power generation

Technical terms

Amine-based post-combustion – CO_2 capture technology using chemical absorption

Carbon capture and compression – a process to capture CO_2 gas and compress it to flow in a pipeline for injection deep underground

Miscible flood operations – a displacement process in oil reservoirs that maintains pressure and improves oil displacement by reducing the interfacial tension between oil and water

Post-combustion – one of three main approaches to capturing CO_2 from the combustion of fossil fuels, occurring after burning the fossil fuel source; other processes include pre-combustion and oxy-fuel combustion

Supercritical CO_2 – a state of carbon dioxide in which it expands like a gas but is in a fluid state

INTRODUCTION: RESEARCH OBJECTIVES AND METHODOLOGY

RESEARCH OBJECTIVES

Canada and other nations are transitioning their energy systems to address climate change.[2] This process is complex in political, social, economic, and technological terms. It requires comprehensive integrated approaches that solve for both energy and climate concerns and garner the support of society, communities, industry, and citizens.

In its first three years (2015-2018), Positive Energy identified major weaknesses and gaps in decision-making processes for energy infrastructure projects, particularly the roles of communities (Cleland et al., 2016a) and the respective roles of public authorities (policymakers, regulators) more broadly (Bird, 2018; Cleland and Gattinger, 2017; Fast, 2018; Simard, 2018). In its current phase of research and engagement (2019-2021), Positive Energy is focused on how to build and maintain public confidence in energy decision-making in an age of climate change, including how public authorities can address polarization over energy and climate. An important component of this work is exploring the role of energy technologies that are critical to reducing greenhouse gas (GHG) emissions, but that may be politically controversial for various reasons.

Positive Energy's research to date underscores that government and industry investment will need to address and balance both adaptation and mitigation (Cleland and Gattinger, 2019). Within the mitigation context, the research has revealed that social acceptance of new technologies to reduce emissions will significantly influence the pace and extent of emissions reductions (Fast and Gattinger, 2018). Likewise, studies have highlighted the role of underlying factors that affect public confidence in the policy/regulatory decision-making systems that support or reject technology deployment. Specifically, Positive Energy research on public engagement, on policy-regulatory relations, and on community satisfaction with project decision-making, has demonstrated that poorly designed decision processes result in declining trust in policymakers, proponents and/or regulators (Bird, 2018; Cleland et al., 2018; Simard, 2018).

This study forms part of this broader research agenda, and is focused specifically on decision-making processes for carbon capture utilization and storage (CCUS) technologies. For over fifteen years, this climate change mitigation technology has been identified as an important option for CO_2 emissions reductions at large point sources such as fossil-based electricity generation and heavy industry sites (IEA, 2019a; IPCC, 2005). The research addresses the following question:

> *What are the key risk issues related to polarization and public confidence over CCUS and government decision-making processes that govern and support it, and how might they be addressed?*

We use the term public confidence broadly to indicate the overall support and comfort that the public has for a given energy system and its associated regulatory scheme (social acceptance, discussed below, is one aspect of public confidence). Public confidence can be strongly affected by issues that are polarized amongst the public, government entities or other stakeholders. We use polarization to describe situations in which opinion or policy approaches have diverged into opposing perspectives, with little middle ground or room for compromise. Polarization can be problematic for policy and regulatory efficacy, leading to policy and regulatory swings and lack of consistency.

2. Co-benefits are expected to accrue to other cumulative environmental impacts such as air and water quality.

As discussed in this report, a broad range of risk issues related to CCUS emerged at two levels: 1) CCUS as a climate mitigation technology at the international/national/provincial levels (hereafter, the policy level); and 2) specific CCUS projects and related government decision-making processes at the provincial / regional / local levels (hereafter, the project level). Risks at both of these levels influence the extent of policy support for CCUS, as well as final project-level investment decisions. These risks affect all sectors attempting to manage GHG reductions: large industrial emitters, electricity generation and transmission, transportation, the built environment, agriculture, forestry, waste, and government operations (Specific Mitigation Opportunities Working Group, 2016).

When it comes to energy transition technologies like CCUS, social acceptance has become one of the most policy-relevant concerns (Gaede and Rowlands, 2018; Upham et al., 2015). Two issues are particularly important for new technologies. First, social acceptance can be thought of as a continuum, a range of positive and negative responses for both the outcome of a decision-making process and the process itself. As suggested by Batel et al. (2013), societal responses may take the form of a simple lack of opposition, or they may reflect stronger, positive reactions such as support, interest, or even admiration. On the negative side, rejection can include degrees of uncertainty, resistance, or apathy. Second, societal responses are not static: stakeholders' views and innovation contexts evolve throughout a public policy cycle (Busse and Siebert, 2018). For example, at the project level, local context matters a great deal (i.e., for communities adjacent to facilities). Moreover, individual reactions may increase or decrease the risk perceptions of others, in what Kasperson et al. refer to as the social amplification of risk (1988).

At the national level, recent Positive Energy survey research shows that Canadians strongly support the development of renewable energy, and 74 percent expect a transition to a clean energy economy within 25 years (Bird et al., 2019). Further, a majority (52 percent) believe that fossil fuel development is compatible with meeting climate objectives. CCUS technologies are critical for the success of these goals. At the same time, Canadians tend to be polarized along partisan lines over carbon taxes and the expansion of fossil fuel development. These beliefs offer important context for understanding the path forward for CCUS, and the importance of attending to public confidence and polarization in decision-making.

It is important to note that the challenges discussed above exist within a broader context of other factors described by Cleland and Gattinger (2018, 2019) that have fundamentally transformed the context for energy decision-making. These include lower levels of public trust in institutions of various sorts, greater expectations on the part of citizens and communities to be involved in decisions that affect them, greater political fragmentation and tendencies towards polarization, the need for adaptation and resilience in the energy system itself, and growing levels of economic, political, and technological uncertainty.

RESEARCH METHODOLOGY

In addition to analysis of peer-reviewed academic literature and government documents, this report is informed by interviews and engagement with fourteen decision-makers working within the carbon capture ecosystem, most of whom have an interest in advancing carbon capture mitigation options and outcomes. Within this ecosystem, the participants were chosen to provide a range of perspectives spanning policy development and implementation from the federal government, research and funding institutions, the private sector (fossil and trade-exposed industries, including technology developers and users), and environmental and carbon capture advocacy NGOs.

Scholars characterize this kind of network as an 'epistemic community' or knowledge-based network of recognized experts. They typically have common "principled and causal beliefs but also have shared notions of validity and a shared policy enterprise" (Haas (1992) cited in Stephens et al. (2011, p. 379)). Such a community is usually focused on "risks to" the advancement of the technology as opposed to "risks of" the technology, the latter often being the public's concern (Stephens et al., 2011). In the international epistemic community for CCUS, Stephens et al. (2011) identified a prevalence of those representing business, government, and academia, with a more limited participation of individuals representing non-government organizations.

Semi-structured interviews occurred by telephone in May and June 2019. The findings are organized in part by distinguishing between group types. This may be based on the organizational type (government, industry, non-government); industry type (oil, gas, and coal, or trade-exposed); or those working directly with the technology ('implementers'). The latter excludes those who view the technology as one policy option for emissions reductions among many. Participant affiliations and the interview guide are provided in Appendices 1 and 2, respectively.

We use a risk-based framework for the analysis (Rothstein et al., 2013). Risk assessment and risk management (RA/RM) has been applied for decades to health and environmental protection, and public safety, as well as issues in banking, insurance, and organizational management. If done well, RA/RM provides a systematic, open, and transparent process for stakeholders and decision-makers to follow. Similarly, it can be used as a framework for analysis, as we do here (see Box 2).

BOX 2: RISK ASSESSMENT AND MANAGEMENT

- In general, risk assessment (RA) includes steps for stakeholders to understand the context, estimate the likelihood and severity of the consequence of factors (determine their risk), and identify risk control options that could reduce potential adverse outcomes (harms) to health, the environment, the economy, politics, or even reputation.

- Subsequent steps in risk management (RM) then focus on the decision-maker choosing an option to mitigate the risk, often characterized as regulatory, economic, advisory, community-based, or technological approaches, or a combination thereof.

- With ongoing engagement, stakeholders implement, monitor, evaluate and adjust mitigation options such that lower and tolerable levels of risk are achieved.

Source: Adapted from Krewski et al., 2007

The risk issues discussed here were primarily chosen from the findings of L'Orange Seigo et al. (2014), where the technology acceptance framework of Huijts et al. (2012) was applied to public perception of CCS. The list is supplemented by risk issues identified by Leiss and Krewski (2019) as being "most likely to attract wide public attention and thus . . . likely to have, in the long run, significant influence on the public acceptance of CCS" (p. 239).

Specifically, we categorize the risk issues that affect public confidence in CCUS decision-making into three groups. The first category (seven risks) comprises ***cross-cutting factors*** for all parties (government, industry, and the public):

1. Worldviews
2. Problem perception
3. Trust
4. Energy context
5. Knowledge / information provision
6. Tolerable costs
7. Distributive justice

The second category relates to ***governance factors*** (three risks):

1. Policy and regulatory stability
2. Inter-jurisdictional challenges
3. Procedural justice

The third category focuses on ***industry factors*** (three risks):

1. Willingness and/or capacity to act
2. Pace / demonstration of technological feasibility
3. Market competitiveness / international trade

Definition and discussion of these thirteen risk issues, based on the literature and the interviews, is provided in Research Findings. Importantly, in an effort to identify actions to mitigate these risk issues for both polarization and public confidence in decision-making processes, we also identify whether options are under the purview of government policy, government regulation, or industry action.[3]

Several key recommendations emerge from the analysis, including the need for a national vision for CCUS, a continued need for carbon pricing, the need for government and industry to develop climate change and GHG reduction plans using transparent engagement processes, and the need to strengthen CCUS as a mitigation strategy with a focus on storage strategies and uses beyond the fossil fuel sector.

3. When we use the term industry action, we are solely focusing on large point sources of emissions.

REPORT OUTLINE

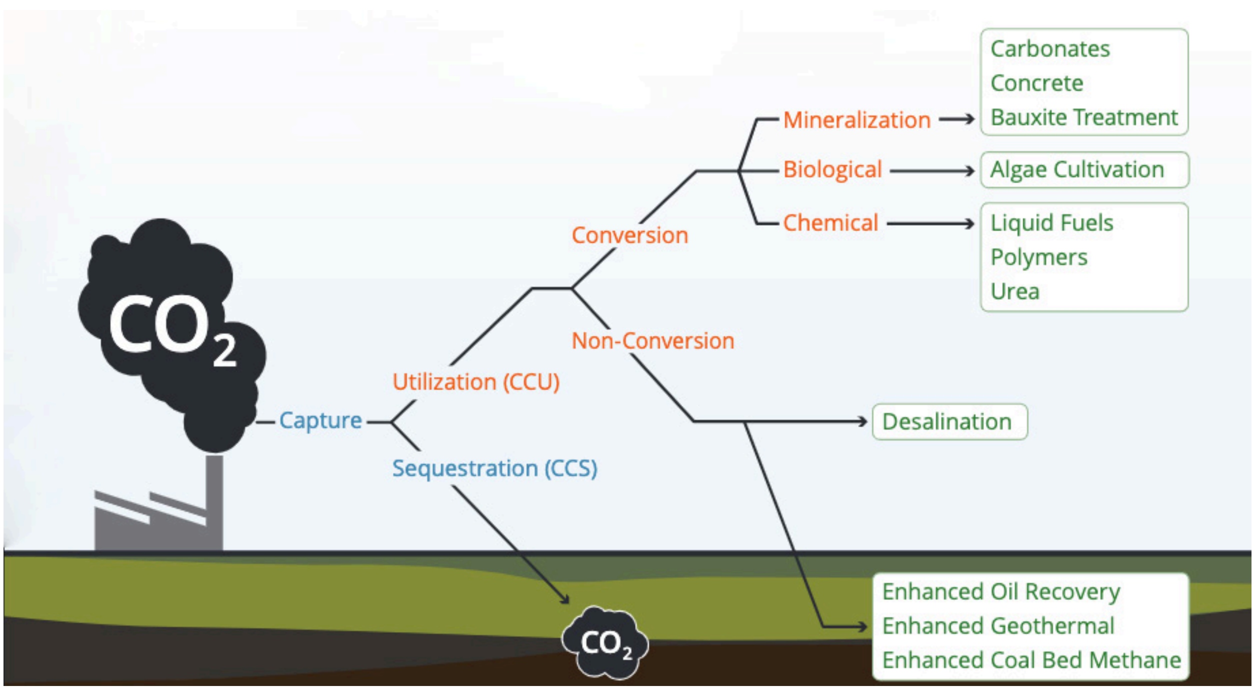
We begin with a brief overview of carbon capture technological processes and implementation options in A Primer on Carbon Capture, Utilization and Storage, including the Canadian policy and project context. Research Findings provides the results from our research interviews. This comprises a summary of the participants' common or divergent views of the thirteen risk issues, including suggested risk management options that could be undertaken through government policy, government regulation, or industry itself. Importantly, participant responses are not polarized, as they are generally supportive of the potential role of CCUS in GHG mitigation. Rather, their assessments help to identify which aspects of CCUS could be most challenging or polarizing for implementation in Canada. Discussion and Recommendations for Action lays out recommendations to manage risk issues with a view to enhance confidence in CCUS decision-making processes. The final section looks forward to future research and action.


HP CO2 TO ACTL

A PRIMER ON CARBON CAPTURE, UTILIZATION AND STORAGE

Integrated carbon capture and storage technologies may be applied to CO_2 emissions at point-source fossil energy electricity generation and heavy industry sites. Demonstrated applications include carbon capture with saline aquifer sequestration (CCS); carbon capture, utilization and storage, such as for enhanced oil recovery (CCUS/EOR); and carbon capture and conversion in emissions-intensive and trade-exposed (EITE) industries such as cement, steel, and chemical manufacturing (see Figure 1; sequestration can also be used for EITE industries).[4]

FIGURE 1: CARBON CAPTURE, UTILIZATION AND STORAGE APPLICATIONS



Source: with permission from ICO2N and Pembina Institute (2015)

4. The glossary describes the organizations, project types, and technical terms used in this section.

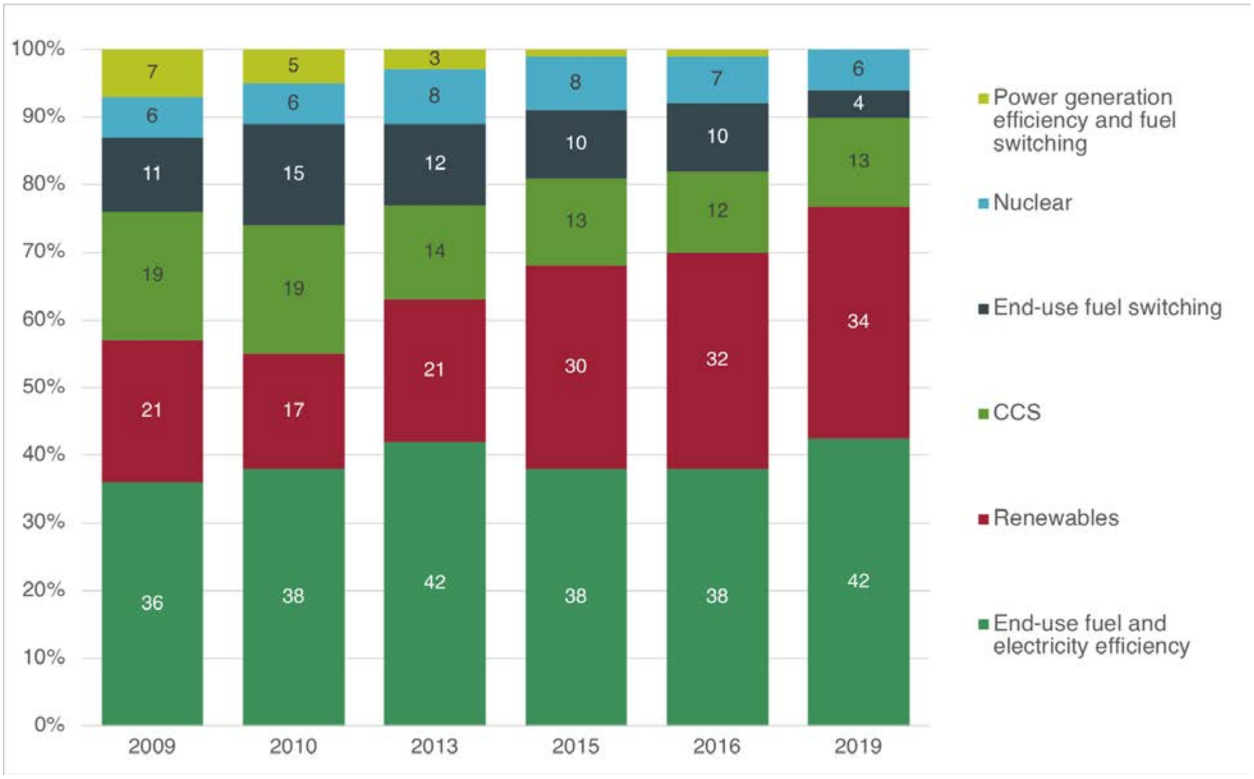
CCS and CCUS technological processes include large-scale integrated projects (LSIPs – definition in the glossary) at coal and natural gas electricity generation stations and upstream oil and gas facilities. LSIPs include four activities: capture, transport, deep well-head injection, and storage.

Globally, LSIP CO_2 capture may be undertaken using pre-combustion, post-combustion, and oxy-fuel technologies (Gale et al., 2015). The capture activity also includes compression of the CO_2 emissions into a supercritical state, with the CO_2 concentration approaching 99 percent pure. This substance is usually transported by pipeline to the injection site.

Beginning in the early 1970s, supercritical CO_2 was injected into depleted oil reservoirs to improve miscible flood operations for enhanced tertiary oil recovery (EOR) purposes. At the time, this was not conceived as a climate mitigation strategy because CO_2 procured for EOR was seen as a cost to be reduced while at the same time enhancing oil production.

The IPCC Special Report on carbon dioxide capture and storage (2005) put a spotlight on CCS as a climate change mitigation option, with sequestration of CO_2 in saline aquifer formations 800-1200m deep underground. For its part, the International Energy Agency (IEA) has consistently included CCS as a lowest-cost GHG emission reduction solution for point-source emissions sites through 2050. However, the projected CCS contribution to mitigation has been in decline under a variety of emissions reduction scenarios proposed by the IEA since 2009 (Figure 2). This is principally due to slower than anticipated near-term deployment of the technology and also because of improvements in renewable technologies, particularly wind and solar.

FIGURE 2: PROJECTED TECHNOLOGICAL CONTRIBUTIONS TO INTERNATIONAL GHG EMISSIONS REDUCTIONS THROUGH 2050 (YEAR OF PROJECTION)



Note: the IEA (2015) defines 'power generation efficiency and fuel switching' to include GHG reductions from efficiency improvements in fossil electricity, co-generation and heat plants, and a change to less carbon-intensive fossil fuels (for instance from coal to gas). This contribution decreases as end-use fuel and electricity efficiency increases because improving the efficiency of electricity end uses mitigates emissions while also achieving further fuel savings in power generation.

Source: prepared by Larkin with projections from IEA (2009, 2010, 2013, 2015, 2016, 2019b)

There has instead been a propensity towards more EOR (enhanced oil recovery) projects (GCCSI, 2018) with CCS and EOR reframed as carbon capture utilization and storage (CCUS) beginning in 2012 (Markusson et al., 2017). Given the high costs of CO_2 capture, however, Dixon et al. (2015) argue that CO_2 sales for use in EOR projects have been critical to demonstrating the concept, and verifying storage longevity. For example, the Weyburn-Midale EOR project in Saskatchewan was established in 2000 and was subject to a decade of biosphere and geosphere monitoring programs (Bowden et al., 2013a, 2013b).

With respect to the EITE sector, one of the current emphases for emissions reductions is on carbon conversion via chemical or biological processes rather than underground sequestration / storage. This emerging era is focused on the use of CO_2 emissions within an industry, such as for cement manufacturing, or offered as a valued carbon feedstock in the downstream industry marketplace, such as chemicals, plastics, or fuels (Jones et al., 2017).

Reports on barriers and benefits of CCS, CCUS, and carbon conversion have been published at the global level (see for example IEA (2020b), which examines CCUS technologies for energy infrastructure as well as hard to reach emissions in the EITE sector). In addition, the IEA's Energy Technology Perspectives 2020 flagship report (IEA, 2020a) broadens the analysis beyond CCUS to over 800 technology options that could be applied to reach net-zero emissions by 2050.

Participants in this study noted that 'CCUS' functions as the umbrella term for CCS, CCUS, and conversion. Additionally, the term 'CarbonTech' has been used to encompass all carbon capture technologies and technological processes to reduce CO_2 emissions (CMC Research Institutes and Canadian Business for Social Responsibility, 2019). The acronym CCUS will be used for the remainder of this report, unless CCS is highlighted specifically.

CCUS IN CANADA

Public authorities, CCUS companies, and CCUS advocacy organizations across Canada are among the global leaders in support and development of this mitigation technology. They have substantial expertise in policy, regulatory, and technological innovation. Table 1 provides key Canadian and international milestones in four categories of activities: Reports, Agreements and Legislation; Research and Funding; Canadian LSIPs; and International, Bilateral and Canadian Stakeholder Organizations and Initiatives.Canada's three broad sectors with potential to incorporate CCUS are upstream oil and gas production, fossil-fuel based electricity plants, and EITE industries (Larkin et al., 2019a). Table 2 indicates the GHG emissions projection for each sector along with the rated capacity of existing Canadian LSIPs and their approximate contribution to emissions reductions through 2030.

Upstream oil and gas development is Canada's largest source of GHG emissions, accounting for approximately 27 percent of emissions in 2017 and projected to grow to 32 percent by 2030 (Government of Canada, 2019). Shell's Quest CCS project in Alberta, operating since 2015, is the country's showcase LSIP using geological sequestration for emissions sourced at an oil sands upgrader. A portion of the capacity of a second LSIP, the Alberta Carbon Trunk Line for EOR purposes, will use emissions from the North West Redwater refinery.

Electricity generation is Canada's fourth-largest source of GHG emissions (about ten percent) and emissions are projected to decline to 4 percent of the total by 2030 (Government of Canada, 2019). This is primarily because of the federal Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations (Environment Canada, 2018) and Regulations Limiting Carbon Dioxide Emissions from Natural Gas-fired Generation of Electricity (Government of Canada, 2018). Currently, CCS is the only functioning technology that can reduce emissions from fossil fuel-fired power plants (Canadian Electricity Association, 2020). SaskPower's Boundary Dam coal-fired electricity plant is Canada's only LSIP operating in this domain.


CO2 TO PIPELINE

TABLE 1: CCUS TIMELINE: CANADIAN AND INTERNATIONAL MILESTONES

Year	Reports, Agreements & Legislation	Canadian Research and Funding	Canadian Large-Scale Integrated Projects	International, Bilateral and Canadian Stakeholder Organizations and Initiatives
1991		NRCan's Canmet facility began CO_2 capture research (ongoing)		IEA GHG R&D Programme
2000		Weyburn EOR operations project operational (approved 1997) NRCan's Canmet facility began CO_2 storage research (ongoing)	Weyburn EOR project, Saskatchewan, with CO_2 source from North Dakota	Petroleum Technology Research Centre founded, Regina
2003				Carbon Sequestration Leadership Forum established; Canada is a member
2005	IPCC Special Report on Carbon Dioxide Capture and Storage	~$3B in federal & provincial funding for pilot large-scale integrated projects over next decade	Midale EOR, Saskatchewan; extension of Weyburn, with CO_2 source from North Dakota	
2006	Canada's CCS Technology Roadmap			
2008	Alberta and Federal Government ecoEnergy CCS Task Force Report		Quest oil sands upgrader sequestration project, Alberta, proposed	Canadian CCS Network created by Council of Energy Ministers Pembina Institute & Univ. of Calgary's ISEEE host CCS Forum
2009	IEA *Technology Roadmap*: Carbon capture and storage	Carbon Management Canada Network of Centres of Excellence opens	SaskPower's Boundary Dam project approved $250M federal contribution	US-Canada Clean Energy Dialogue Canada joins Global Carbon Capture Storage Institute
2010				Clean Energy Ministerial established; Canada is a member
2011	Alberta begins CCS regulatory framework assessment		Alberta Carbon Trunk Line (ACTL) approved $495M funding from Alberta; $63M federal contribution	

2012	CSA Standard, Geological Storage of CO_2		Quest oil sands upgrader sequestration project approved $745M funding from Alberta through 2025; $110M federal contribution	North American Carbon Storage Atlas completed
2013	Alberta acts and regulations enabling sequestration (ongoing) Publication – Alberta CCS regulatory framework assessment	CMC Research Institutes established Alberta $35M Grand Challenge for CO_2 conversion into high-value products	SaskPower's Boundary Dam capture technology approved	
2014		CMC Network of Centres of Excellence concludes	SaskPower's Boundary Dam project operational	
2015	IEA publishes Carbon capture and storage: *The solution for deep emissions reductions*		Quest carbon capture and storage project operational	
2016	IEA publishes *20 Years of CCS* Pan-Canadian Framework on Clean Growth and Climate Change (see also Appendix 3) BC CCS Regulatory Policy Framework initiated			International CCS Knowledge Centre established, Regina
2017	Alberta Research and Innovation Framework created to support carbon utilization solutions for industry	Federal budget includes $155M federal Clean Growth Program (details for CCUS in Appendix 3)		
2018	Federal Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations	Finalists of NRG COSIA Carbon XPrize incl. four Canadian companies Alberta opens Carbon Conversion Technology Centre		CMC Research Institutes and Pembina Institute – *CCUS: Priorities and Pathways Workshop*
2019	Federal Regulations Limiting CO_2 Emissions from Natural Gas-fired Electricity	Call for CCUS projects by Natural Gas Innovation Fund (created by Canadian Gas Association)		
2020	Federal national targets to achieve net-zero emissions by 2050 *IEA Energy Technology Perspectives*	Alberta invests $80M in CCUS for industrial energy efficiency Ottawa invests $100M in Clean Resource Innovation Network (includes funding for CCUS)	Alberta Carbon Trunk Line operational	CMC Research Institutes, ACTIA and Pembina Institute evaluation of national carbon conversion technology development competitiveness

TABLE 2: ESTIMATED CO_2 EMISSIONS, STORAGE CAPACITY, AND EMISSION REDUCTIONS FOR EXISTING LARGE-SCALE INTEGRATED PROJECTS (LSIPS)*

CCUS application	GHG Emissions % of Canadian Total ($MtCO_2$-equiv[a]) Reports, Agreements & Legislation			Canadian LSIPs	
	2015	2020 (est.)[b]	2030 (est.)[b]	Project with rated capacity	Approximate contribution to national emissions reductions[c]
Oil and gas sector (predominantly Western provinces production and refining)	~26% (192)	~30% (206)	~32% (213)	Quest CCS • 1.2 $MtCO_2$/yr • Total 27 $MtCO_2$ by 2040 Alberta Carbon Trunk Line (ACTL) (EOR)[d] • Capture at North West Redwater upgrader • 1.2 $MtCO_2$/yr initial flow	1.16% 2020 1.13% 2030
Electricity sector (Coal-fired power in Alberta, Saskatchewan, New Brunswick, Nova Scotia)	~11% (81)	~8% (52)	~4% (24)	Boundary Dam (EOR) • 1.0 $MtCO_2$/yr	1.92% 2020 4.16% 2030
Heavy Industry (Includes emissions-intensive and trade-exposed sectors such as cement, steel and fertilizer)	~11% (77)	~11% (77)	~13% (84)	Nutrien Plant (portion of ACTL) • 0.585 $MtCO_2$/yr	0.76% 2020 0.69% 2030
Total	722	682	658	3.985 $MtCO_2$/yr	3.84% 2020 5.98% 2030

*GHG emissions from Government of Canada (2020); project detail from Larkin et al. (2019b).

a Overall in Canada, an estimated 79% of GHG emissions is CO_2. There is insufficient information to calculate the CO_2 gas component of these projections.

b Projected with federally announced measures aimed at reducing GHG emissions, such as regulations, programs, and funding. Given the COVID-19 pandemic, these may be under- or over-estimated.

c Calculation: total project capacity as percent of projected emissions.

d The ACTL has a 14.6 $MtCO_2$/yr flow capacity so contributions to emissions reductions (final column) could increase significantly.

With respect to the application of CCUS for heavy industry outside oil and gas production, this is another area with strong potential: approximately eleven percent of GHG emissions originated from heavy industry in 2017 and emissions are projected to grow to approximately thirteen percent by 2030 (Government of Canada, 2019). The IEA (2019c) suggests that emissions reductions in iron and steel, cement, aluminium, and chemical industries remain particularly difficult. Alberta's Carbon Trunk Line, noted above, will use CO_2 sourced in part from the Nutrien fertilizer plant. Carbon conversion may be applied to a greater extent for the EITE sector, as the cement and pulp and paper industries are demonstrating.

With the federal government's proposed legislation targeting net-zero emissions by 2050 (House of Commons of Canada, 2020), bioenergy with CCS (BECCS) may become increasingly relevant as an application. In this process, biomass growth such as trees or crops first removes carbon during the growing cycle, followed by capture of emissions when burned as a fuel source, with injection and permanent storage underground as for other sources of CO_2 noted above. Fuss et al. (2014) argue, as with other options, that the potential for negative emissions from options like biomass growth or direct air capture of CO_2 will be part of wider mitigation efforts and deployment will depend on the costs, risks, and timing of other mitigation options.

RESEARCH FINDINGS

CCUS: IS IT CONSIDERED CLEAN TECH?

A key consideration in this research concerns the term 'clean technology' and its relevance to CCUS now and into the future. CCUS is an important component of energy transition – whether or not the technology is considered 'clean' in both political and policy terms is important.

Statements and objectives for a number of international and Canadian organizations illustrate the place of CCUS in clean energy and/or clean technology (see Appendix 3). All initiatives define CCUS as part of clean energy and clean technology. The application of carbon capture for clean electricity (i.e., post-combustion capture) is sometimes identified separately from other clean energy technologies like renewable power using wind and solar energy.

Internationally, the Clean Energy Ministerial, a partnership of global economies – including Canada – working together to accelerate clean energy transition, includes CCUS alongside other clean energy strategies and technologies, such as improving energy efficiency and management, implementing electric vehicle initiatives, supporting construction of sustainable buildings, and transforming the built environment (Clean Energy Ministerial, 2019a, 2019b). The IEA's *Sustainable Development Scenario* (2019e) includes CCUS in both the 'industry and transformation' and 'electricity' sectors. The Pan-Canadian Framework on Clean Growth and Climate Change (Government of Canada, 2016) includes the overall goal of capturing CO_2 emissions before they are released into the atmosphere.

In addition, CCUS initiatives are included in Statistics Canada's *Environmental and Clean Technology Products* account as activities that provide environmental protection through pollution prevention, reduction, or elimination.

With respect to funding opportunities, CCUS is likewise considered clean tech. For example, the Canadian federal government's $155 million *Clean Growth Program* accepts applications for research, development and demonstration, including carbon capture, for the reduction of GHG emissions in the energy or mining sectors. The private sector is supportive through the Natural Gas Innovation Fund (NGIF) and the NRG-COSIA Xprize. The NGIF is a $1.5 million fund that includes a focus on capture system technologies for natural gas distribution (among other eligible projects). The latter initiative is a $20 million global competition for CO_2 conversion into usable products. Xprize semi-finalist review criteria include CO_2 uptake, the economic value of the product created, product market size, and environmental footprint. Canadian companies are among the finalists.

In addition to reviewing statements, objectives and programs of international and Canadian organizations, this study explored whether energy and environmental leaders perceive CCUS as clean tech. The first section of the interview guide asked participants for their views on clean technology in general, as well as whether CCS, CCUS, and carbon conversion meet their criteria for clean tech (see Appendix 2 for the interview guide).

Government and fossil fuel industry participants noted that clean tech was often linked to non-GHG emitting energy, such as wind, solar, nuclear, and hydroelectricity. In contrast to others (see below), these participants did not make a connection between clean tech and wider metrics related to sustainable development, for instance, whether clean tech is associated with concomitant economic and social development, or if criteria for clean tech create material negative impacts on other social or environmental features or values.

For participants representing emissions-intensive and trade-exposed industries, research entities, and nongovernment organizations, clean tech criteria included the following:

- the technology results in a substantial and measurable net decrease in GHG emissions
- the environmental benefit is a core element of the value proposition
- there is improvement to environmental / economic / social performance of a process or product, possibly using a sustainability lens or lifecycle analysis approach

Moreover, as an exclusionary or threshold criterion, these participants suggested that clean tech should not result in material negative impacts to other environmental or health values, beyond GHG emission reductions, such as impacts on water or air quality.

In addition, representatives of funding agencies and research organizations raised the economics of clean tech, including the associated goals of:

- job creation and economic diversification
- export development
- uses / solutions for emerging sectors

These differences in perspective on the criteria for 'clean tech' are interesting, and suggest that there may be (at least) two ways of conceiving of clean tech: a narrower conception that focuses on emissions reductions, and a broader conception that extends to considering other environmental, health or economic impacts beyond emissions. Which conception will dominate over time remains to be seen. (Of note, as shown in Appendix 3, the federal *Clean Growth Program*, to which carbon capture projects are eligible, includes evaluation criteria for environmental and economic / social impacts of proposals).

Despite the differences noted above, participant views were aligned on a variety of other issues. Almost all people noted that clean tech needs to be cost effective and economically competitive beyond business as usual (BAU). That is, the choice to implement clean tech should not result in a net increase in production expenditures.

When it came to participant views on CCS, CCUS and carbon conversion, interviewees from all sectors believed these technologies constitute clean tech, albeit with some qualifications:

- For CCS, the pipeline transport distance from the capture facility to the injection site is important, with suitable sequestration formations needing to be located within a reasonable distance from the capture facility;
- For CCUS, it is important to identify and reduce additional (lifecycle) emissions that could result from the technology;
- For carbon conversion, often viewed as a workstream of CCUS, these technologies may have more or less impact on emissions depending on the context.

While there was general agreement that CCUS is part of the clean tech sector, the following discussion brings forward different perspectives on risk issues related to decision-making for the technology.

The second section of the interview asked participants about polarization over CCUS or challenges to public confidence in carbon capture decision-making processes that could affect support for research, development, and implementation. Table 3 categorizes participant responses into cross-cutting, governance, and industry risk issues and indicates which issues emerged as high or lower risk.

The final portion of the interview asked participants to identify risk management options for their top three risk concerns. The following section discusses each of these factors in turn. The final section of this report provides recommendations for action.

RISK ISSUES UNDERPINNING POLARIZATION AND PUBLIC CONFIDENCE

As shown in Table 3, participants' concerns about polarization and public confidence related to CCUS can be categorized into thirteen socio-economic and political risk issues.

- Cross-cutting factors: worldviews, problem perception, energy context alternatives, trust, tolerable costs, knowledge/information provision, and distributive justice
- Governance factors: policy and regulatory stability, inter-jurisdictional challenges, and procedural justice (including competent regulatory authorities)
- Industry factors: willingness and capacity to act, pace and demonstration of technological feasibility, and market competitiveness / international trade

TABLE 3: RISK ISSUES RELATED TO POLARIZATION AND PUBLIC CONFIDENCE IN DECISION-MAKING FOR CCUS*

Note: Number in table (#) represents how many of the fourteen participants raised the risk issue. Shading corresponds to degree of risk identified by interviewees (higher or lower).

Higher risk
Lower risk

Risk issue	Definition
1. Cross-cutting factors for government, industry, public	
Worldviews (10)	The sets of assumptions, beliefs, and experiences that inform stakeholder attitudes towards CCUS
Problem perception (11)	Awareness of problems related to energy systems
Trust (5)	Trust in technical/scientific information, industry, regulatory competence, implementation
Energy context (10)	Trends in implementation of energy alternatives in decision-making jurisdiction
Knowledge / Information provision (12)	Awareness, common understanding, distribution of information
Tolerable costs (12)	Financial
Distributive justice (11)	Distribution of costs, risks, benefits
2. Governance factors	
Policy and regulatory stability (7)	GHG emissions reductions goals and measures that could support (directly or indirectly) CCUS implementation
Inter-jurisdictional challenges (9)	Decision-making process and outcomes that involve two or more jurisdictions
Procedural justice (5)	Transparent, engaged, accountable decision processes, including competent regulatory oversight
3. Industry factors	
Willingness and/or capacity to act (10)	Planning, preparedness, agreement to implement CCUS
Pace / Demonstration (12)	Technological feasibility and implementation
Market competitiveness / International trade (7)	Economic opportunity / export of technologies

*Source: * List of risk issues adapted from Leiss and Krewski (2019) and L'Orange Seigo et al. (2014)*


SaskPower
Boundary Dam

CROSS-CUTTING FACTORS FOR GOVERNMENT, INDUSTRY, THE PUBLIC

Different Worldviews (Higher risk: mentioned in ten of fourteen interviews). Worldviews refer to the sets of assumptions, beliefs, and experiences that inform attitudes towards CCUS. Worldviews fundamentally affect attitudes towards climate change and energy technologies, as well as risk perceptions and preferences for actions that address climate change (Kahan et al., 2011). In so doing, they can shape government policy and regulatory responses, which can have implications for the nature and speed of emissions reductions.

Studies about the development and future of CCS technology have found an uneasy coalition of supportive actors with a variety of viewpoints from industry, government, NGOs, and civil society (Markusson et al., 2012). Opinions at the policy level vary across a range of issues, including how effective the technology is for long-term storage or sequestration, and whether it perpetuates fossil fuel production and use. At the project level, worldviews and their relationship to beliefs about local benefits and safety seem to have the largest impact on social acceptance of CCS (Krause et al., 2014; Warren et al., 2014).

The interviews support much of this existing literature. Respondents noted that for some people, using CCUS/EOR means the technology should not be defined as "clean tech." This relates to a worldview that affects acceptance of CCUS because it perpetuates fossil fuel production and use and is perceived to represent unacceptable risks to the environment. Participants agreed that a variety of actions, such as information provision and a focus on the use of CCUS as part of the climate solution, would be most likely to help lessen this challenge. Other suggestions included developing a common GHG reduction vision in the country, and demonstrating the technology's relevance beyond conventional fossil fuel applications.

"[There is] kind of a moral hazard problem of proceeding with CCS . . . ultimately that by buying into CCS, you are accepting a lesser solution for decarbonization in the energy sector." Interview participant

"Canada can also serve as a leader to other countries in the development of cleaner technologies for oil and gas. In other words, in addition to providing product, Canada can provide solutions to the world for the development of oil and gas resources with lower environmental impact." Interview participant

Differences in Problem Perception (Higher risk: mentioned in eleven of fourteen interviews). This issue is an extension of the risk of different worldviews. It refers to problem perceptions varying across different groups or belief systems when it comes to climate change and the place of carbon capture as a mitigation option. Study participants emphasized this issue as very important.

Previous Positive Energy research has identified two expectations for energy transition among the general public and among energy and environmental leaders: one focused on a gradual process of change and the other focused on aggressive emissions reductions (Beck with Richard, 2020; Bird et al., 2019). Positive Energy survey research reveals that a majority of Canadians expect a moderate pace of reducing GHG emissions with expectations for substantive change in 25 years, while a minority expects a more aggressive pace of ten years (Bird et al., 2019). Transition expectations can fundamentally affect perceptions of CCUS as a solution or a problem.

As noted above, existing CCS scholarship has found EOR to be controversial because it does not address the production of downstream GHG emissions or look at alternative (non-fossil fuel) energy sources (Einsiedel et al., 2013). Indeed, interviewees' remarks regarding problem perception suggested that discussions of CCUS technologies should not focus on capture, but about what is done with the CO_2, including what else can usefully be done to reduce emissions in sectors with limited opportunities. In the EITE sector, differences in problem perception may be muted because the question of carbon storage includes the potential for conversion into a product (rather than storage as a waste or in increasing fossil fuel production).

Key suggestions to address differences in problem perception included the development of carbon capture with permanent storage and/or conversion destinations, the need for tax incentives to mobilize the EITE sector and accelerate the pace of CCUS technology beyond EOR, and better outreach and communications for the actions being taken. Respondents believed that progress in these areas would minimize the risk posed by differences in problem perception.

> *"[. . .] it's almost like an identity crisis, I think, that Canada is facing now. [When it comes to] the role of its fossil fuel resources and in the context of its attempts to be a climate leader on the global stage, [there is] a lot of hand-wringing and heated debate and rhetoric around what the right path forward is."* Interview participant

Energy Context Alternatives (Higher risk: mentioned in ten of fourteen interviews). This issue refers to the challenge of trade-offs and opportunity costs of developing one technology over another, especially at the provincial and local level.

Existing literature suggests that public confidence in decision-making for energy alternatives can be strengthened where new technologies are discussed within the broader energy context. For example, Lock et al. (2014) assessed participant trade-offs between CCS and renewable energy sources in situations where one technology is developed at the expense of the other. They found that making these decisions in the context of broader conversations about energy use improved trust and perceptions of legitimacy in government decisions about technology. Stated another way, public confidence in these decisions is affected by peoples' perceptions of fairness in decision-making processes, and their assessments of collective and individual costs and benefits. This applies for all forms of energy and energy projects, from oil and gas through to renewable energy (Cleland and Gattinger, 2017; Nourallah, 2016).

Participants in this study noted that CCUS has the potential to achieve multi-billion dollar markets internationally, but it is challenged by increasingly affordable natural gas, wind, and solar technologies. To address potential trade-offs in the energy context, interviewees recommended including more coherent and comprehensive approaches to decision-making at all jurisdictional levels. Such approaches would presumably make clear some of the underlying benefits of CCUS in comparison to other technologies. Suggestions to highlight the value of CCUS included ongoing community education and outreach for CCUS science and safety, research to make the technology more affordable, and efforts to better understand the potential role of CCUS in contributing to net-zero emissions.

"[CCUS] work that's been done in utilities and [the] oil and gas sector will be tremendously beneficial [. . .] across a broader range of sectors that we know are going to be here to stay." Interview participant

Lack of Trust (Lower risk: mentioned in 5 of fourteen interviews). Lack of public trust in project developers, public authorities, and decision-making processes can be a significant impediment to public confidence in energy project decisions. Research demonstrates that trust is a critical factor in social acceptance of energy project decisions (Cleland et al., 2016b; Cleland et al., 2018; Nourallah, 2016), including for CCS (Einsiedel et al. (2013, p. 156). This is due in part to levels of trust in new technologies – communities can be skeptical of non-established science and infrastructure.

Interestingly, interviewees emphasized the importance of trust to a lesser degree than other risk factors, but they did raise it as an issue. Respondents noted the critical importance of trust in science. They also highlighted the importance of trust in industry, particularly if CCUS pursuits are seen as self-serving and not a response to community or broader needs. They suggested that policy longevity and stability are essential to promote trust in government, particularly the trust of industry. Industry participants noted that individual actions by their own sector could undermine trust in the entire CCUS endeavour (for instance, the potential negative health and environmental impacts associated with the use of amine-based post-combustion capture technology).

"[There can be] suspicion, skepticism [of] industry . . . where [a technology] is pushed by industry – [people think] there's got to be a catch. If industry tends to be self-serving rather than serving a social good, 'How can this be a good thing?'" Interview participant

Tolerable Costs (Higher risk: mentioned in 12 of fourteen interviews). Concerns over cost emerged as one of the strongest risk issues for all participants, but they took on a variety of forms. The cost issue begins with initial investments in the technology without knowing the outcome. By extension, this means high levels of financial risk. Here, participants noted that arguments can be made for public money to be spent instead on renewables, nuclear, or direct air capture of CO_2. As for private spending, it tends to focus on lowest cost solutions, which also represents a risk that investment dollars won't flow in sufficient volume to CCUS.

There are also regional dimensions to the cost issue. Previous Positive Energy research has shown that energy and environmental leaders are concerned that the costs and opportunities of transition are unlikely to be distributed equally across Canada (Beck with Richard, 2020). In this study, participants also noted that variations in government funding between jurisdictions can have different regional cost/benefit impacts.

Further, participants expressed concern that if capture innovation is subsidized by government it could lead to negative public perceptions because of concern over government favouritism of fossil fuels.

Interviewee suggestions for managing these risks included avoiding punitive regulations or generous grants/subsidies, and instead focusing on more moderate programs of public support through tax incentives, supportive policy, and research support through effective demonstration and pilot projects.

"Some technical problems are mostly cost related and [they go] back fourteen, fifteen years . . . those impressions are hard to unseat. You know people are like 'Oh no no, we tried that and it cost a fortune, so we don't do that anymore.'" Interview participant

Inadequate Knowledge / Information provision (Higher risk: mentioned in 12 of fourteen interviews). Participants noted that inadequate knowledge-sharing and information provision slow down or block CCUS acceptance at the policy and project levels. While scientific and engineering expertise was underlined as a positive attribute in the Canadian context, participants also noted that public knowledge of the underlying technology and functions of CCUS infrastructure remains low. They expressed similar concerns over limited knowledge levels among politicians (as compared to the working level bureaucracy) and environmental stakeholders.

Academic research demonstrates that increasing knowledge is necessary, but not sufficient, when it comes to fostering social acceptance of technologies or projects (Baekgaard et al., 2017; Cleland et al., 2016b). Participant concerns mainly focused on the degree of knowledge about market risks, challenges, and specific attributes of the technology.

Suggestions to mitigate risks related to knowledge and information included developing a supportive narrative, improving industry outreach, and better information and resource sharing amongst technology developers. In addition, participants emphasized that there may be stronger support for CCUS as an emergent technology for the EITE sector.

> *"[The technology is] not that well understood actually. There's a risk that policymakers and governments – and I've seen this – are kind of interested but they don't know what to do with it. . . . Especially at the higher policy levels of the government they don't really understand it, even though government scientists may understand it fairly well."* Interview participant

Distributive Justice (Higher risk: mentioned in eleven of fourteen interviews). This issue encompasses policy and project decision-making that involve trade-offs and allocation of costs and benefits among different groups. In general, policy discussions in Canada and elsewhere have emphasized that options for climate change mitigation should not unfairly impact vulnerable or minority populations. At the project level, the concern is whether impacts are distributed equitably across the whole of a community and that that community is not unfairly impacted compared to other communities. Concerns for environmental impacts related to post-combustion technologies or to pipeline and CO_2 leakage to the surface, have the potential to impact specific areas or jurisdictions, and may be distributed inequitably within or across communities.

Study participants suggested that risk mitigation measures could include socializing costs across local and provincial jurisdictions, ensuring strong and effective regulatory standards, and improving information using lifecycle analysis. Participants also noted the importance of better communicating health and safety standards, and more effectively identifying and supporting stakeholders who stand to lose if industries shut down.

GOVERNANCE FACTORS

The next three risk issues relate to governance. Policy and regulatory stability for GHG emissions reductions can affect support (directly or indirectly) for CCUS implementation. Inter-jurisdictional challenges concern decision-making that involves two or more jurisdictions. Risk issues related to procedural justice are focused on decision-making processes, including a competent regulatory authority that is transparent, engaged, and accountable.

> *"Stable climate change policy: people are hungry for it."*
> Interview participant

Lack of Policy and Regulatory Stability (Lower risk: mentioned in seven of fourteen interviews). Consistent policies for CCUS mitigation technologies are important, but participants emphasized them less than other factors. Lack of policy stability is problematic because it creates mixed signals for industry and other stakeholders, and because it increases uncertainty in a policy regime in which there are already high levels of political, economic and social risk. This is a particular concern when policies are implemented by a government and then reversed when a new government comes into power. When this happens, it increases mistrust and risk, and weakens the investment climate. Study participants noted that the largest concern for CCUS is variability in provincial and federal carbon policies. Other factors include differences in policy instruments, for instance, using taxes, levies, or performance standards.

Almost all participants noted that a stable price on carbon is essential to mitigate risk. Respondents emphasized the need for cross-partisan agreements both within and between jurisdictions to provide a clear and consistent direction for CCUS technology. They also noted the importance of clear funding models to support innovation, R&D, and investment.

Inter-jurisdictional Challenges (Higher risk: mentioned in nine of fourteen interviews). Study participants voiced strong concern over inter-jurisdictional issues and tensions between provincial governments and between national and provincial jurisdictions. Similar to policy instability, the challenge arises when multiple jurisdictions are inconsistent and unaligned in their approaches to CCUS. For example, Saskatchewan remains committed to coal-fired electricity but the federal government committed to phasing out coal-fired power by 2030. There are misalignments between provinces as well. For example, not all provinces have a regulatory framework for CCUS, and others may include additional reviews of CCUS projects by municipal or Indigenous authorities, creating a hodgepodge of regulatory approaches across jurisdictions.

Participants noted that inter-jurisdictional challenges tend to play out in political and partisan contexts, rather than at the project, bureaucratic or regulatory level. Industry participants also worried that government consultation with industry to develop more consistent policies may be slow to materialize, and that negative public views about a lack of movement to address challenges will fall on industry.

All risk management options suggested by participants involved improving and accelerating cooperation and coordination between governments.

> *"One of the reasons why I don't think we've seen as much uptake on carbon capture is that we collectively never moved forward in an effective way on pricing carbon. We'd always pushed for that consistent price on carbon on a North American-wide basis. We're not there – instead now we're in a federal-provincial quagmire on this issue."* Interview participant

Procedural Justice (Lower risk: mentioned in 5 of fourteen interviews). This issue relates to engagement, transparency, and accountability in policy and regulatory decision-making. There is an extensive literature underscoring that policy processes perceived as open, transparent and unbiased are much more likely to result in public support for both policies and projects (Cleland et al., 2016b; Frank and Girard Lindsay, 2020; Simard, 2018).

Interestingly, this topic did not garner a lot of attention from study participants, but those who mentioned it pointed to risks at both the policy and project levels. Government decision-making needs adequate input from industry and other stakeholders. In parts of Canada, interviewees noted that there are no specific regulations for risk management review. This has the potential to impact public confidence in individual project decisions and implementation. Of note, interviewees did not highlight the need for transparency in the determination of costs and benefits or in lifecycle assessments. It may be that this issue has less "play" with participants because there are so few CCUS projects in Canada or because many of the large-scale projects exist in Alberta, where regulatory provisions are most developed.

Suggestions to mitigate risk for this issue included improving transparency and information-sharing, incorporating broad lifecycle perspectives into industry and project analyses, and third party reviews of applications to government funding programs.

> *"[We will] always start with the regulations and policy. Society feels comfortable and protected through regulations and policy. Listen to their concerns and factor that into how we develop and deploy the technology as well so [. . .] you're bringing [. . .] society into the technology, their involvement and the raising of concerns. [There needs to be a] desire and willingness to listen to stakeholders about their concerns."*
> Interview participant

INDUSTRY FACTORS

Willingness / Capacity to Act (Higher risk: mentioned in ten of fourteen interviews). This risk issue refers to the tension between industry actors that are able and willing to move forward on technology implementation and those that are not. Tension is heightened by public perceptions that industry is lagging when it comes to vigorously moving forward with a clear commitment to finding emissions abatement solutions.

This issue area has inherent structural components for point-source emissions sites. A number of participants stated that some companies are in favour of the status quo and that the speed of the slowest is advantageous. Others noted that the challenge is exacerbated by different approaches taken for different sectors. For example, new building requirements related to carbon inputs could affect the cement industry more significantly than the steel industry. Participants held diverse opinions on this issue.

Beyond the need for government to provide a clearer path on GHG emissions reductions, most recommendations for risk management focused on industry actions, including CEO leadership and coordination, higher investment and cost reductions, and greater commitment to innovation in the project demonstration phase.

"CCUS is going to be implemented for point-source emissions. Do we want to be leaders, laggards, or ho-hum in the pack?" Interview participant

Pace and Demonstration of Technological Feasibility (Higher risk: mentioned in twelve of fourteen interviews). Study participants emphasized this issue strongly and noted the inability to meet technological feasibility expectations in any area of CCUS. Some participants argued that expectations were simply unrealistic and lacked appropriate timelines.
The issue of pace is directly related to many of the other concerns discussed above. Jurisdictional issues, differences in worldviews, alternative technological options, and lack of consistent carbon pricing and policy all play a role in driving pace to a grind. Several participants raised the importance of scaling up the technology to a level that has an effective emissions impact.

Addressing this challenge will require action by industry and government in concert. Recommendations included increasing policy and funding stability, improving cost reductions, strengthening existing partnerships and research networks, and creating new international partnerships.

Market Competitiveness and International Trade (Lower risk: mentioned in seven of fourteen interviews). This area is one of the few bright spots for participants, who characterized it as a strength. Government documents and interviewees emphasize that Canada could be well-positioned to benefit from international markets, and to emerge as a leader in this technology space. Some participants noted that Canada is already considered to be a global leader in the development of CCUS.

In terms of risk management, many participants saw this area as one of strength. Suggested risk mitigation options included demonstrating and showcasing investment, having coherent government policies, building export market opportunities, and developing Canada's role as a global leader in CCUS.

SUMMARY: STUDY PARTICIPANTS' WEIGHTING OF RISK ISSUES

As detailed above, nine of the thirteen risk issues were mentioned by more than half of participants. We categorize these as "higher risk" issues in Table 3 (above) because they are of concern to more stakeholders. With the exception of trust, all *cross-cutting* risk issues were mentioned more frequently; the three *governance* factors were mentioned relatively less often.

The three risk areas mentioned by the largest number of interviewees (12 of fourteen) include: (i) inadequate knowledge and information provision, (ii) the need to reduce costs, and (iii) inadequate pace of effective project demonstration. CCUS is vulnerable in a public and decision-maker context that does not have enough awareness and common understanding of the industry and the broader energy system. Costs (and by extension financial support) are a key concern, especially in terms of being able to make CCUS technologies cost-effective enough for widespread implementation. Finally, the timeline to effective project demonstration is critical in the context of rapid clean energy technology development and climate mitigation solutions. Feasibility and successful demonstration of CCUS technologies need to occur at a pace fast enough to provide solutions.

The following section discusses linkages between the risk issues and the main risk management options identified by interviewees, and provides recommendations for action by government and industry.

DISCUSSION AND RECOMMENDATIONS FOR ACTION

The nations that lead in policy and project support for CCUS include Canada, the United States, Norway, the United Kingdom, and China, with others at lower levels of readiness (GCCSI, 2019). Overall, however, global implementation of CCUS is not on track to meet mitigation projections (IEA, 2019d). Specifically with respect to CCS, a variety of reasons explain limited progress. Viebahn and Chappin (2018) identified policy and project barriers from six perspectives (technical, economic, social, legal, political, and systems); Gaede and Meadowcroft (2016) identified political economy factors including project characteristics, government policy, economics, political-institutional issues, public and political opposition/receptivity, and international dimensions; and Markusson et al. (2017) reviewed the misalignment between GHG reduction strategies like carbon capture and the lack of emissions trading regimes needed to support them. Broadly, this demonstrates that many of the challenges facing CCUS are not unique to Canada.

The first question for respondents in this study asked whether CCUS is an example of clean tech: is it included in the 21st century 'clean tech' basket? Being part of clean tech in an age of energy transition provides funding opportunities and improves perceptions of being part of the solution to climate change. Responses from the interviews, along with analysis of policy and funding documents, indicate that carbon capture, utilization and sequestration, including conversion, meet criteria for clean tech, albeit with some reservations for EOR.

Interview participants were asked to discuss wide ranging risk issues for CCUS and related decision-making processes, along with concerns over public confidence. Although *policy and regulatory stability* did not emerge as a high emphasis issue (Table 3), it is central because of its direct, but secondary effects on industry *trust* in governance arrangements, and related *inter-jurisdictional* challenges in Canada. In addition, policy and regulatory stability affect the perceived and real direction and requirements for industry *pace and demonstration*. Moreover, policy and regulatory stability is linked to the cross-cutting risk issue of *tolerable cost* that affects industry and investor *willingness or capacity to act*. However, participants noted that government support for any mitigation technology has limits: CCUS support cannot be seen as "corporate welfare."

Knowledge accumulation is important for innovation and technology transfer across applications that could be essential for GHG reduction targets. For instance, participants noted that experience and expertise in coal-fired electricity projects could be transferred to relevant newer technologies such as bioenergy projects with CCS. Moreover, a transition from CCUS-EOR (seen as a lesser solution to decarbonization) to carbon conversion in the emissions-intensive and trade-exposed sector could mitigate the risk issue of *different worldviews*. These projects could modify the perception of CCUS as a technology focused exclusively on additional hydrocarbon extraction, which could foster increased and/or broader support.

Participants suggested there may be a more positive story to tell about this technology that could be more acceptable to those wanting an accelerated transition away from oil and gas or to those who are skeptical of the notion of 'clean oil and gas.' Perhaps EITE and non-fossil applications of carbon capture might fare better. *Knowledge and information* provision could emphasize CCUS approaches for emissions reductions in 'hard to reach' sectors. Participants also noted that Canada has strength in readiness related to *market competitiveness and international trade*, potentially valued as a trillion dollar opportunity for CarbonTech in all its applications over the next decades (CMC Research Institutes et al., 2020; CMC Research Institutes and Canadian Business for Social Responsibility, 2019).

Lastly, in order to address risks related to *problem perception* of CCUS as a mitigation option, participants emphasized the need for a widely engaged conversation and planning process involving multiple stakeholders. This conversation should discuss *energy alternatives* across jurisdictions as well as risks related to *procedural* and *distributive justice*, both of which need to be strengthened.

> *"I think the whole sort of ecosystem around [CCUS] – whether it's policy pieces, regulatory pieces and financing pieces – all play a role in how urgently we address the issues."*
> Interview participant

RECOMMENDATIONS FOR ACTION

Recommendations to manage socio-economic and political risks that affect polarization and public confidence fall under the purview of government policy, government regulation, and point-source industry stakeholders, often in concert. We apply a lightly modified version of the REACT framework for risk management and population health (Krewski et al., 2007; Krewski et al., 2014), summarized in Box 2, to categorize the various approaches and tools into policy/regulatory, economic/financial, advisory/communications, community-based, or technological approaches, sometimes in combination. This framework is often used to categorize risk management options for chemical and other hazards that may affect population health, but the five approaches, as modified here, are pertinent to risk management of socio-economic and political risk issues.

This section highlights eleven key risk management recommendations that emerge from our analysis. Table 4 showcases the recommendations, along with additional suggestions made by study participants.

BOX 3: REACT FRAMEWORK FOR RISK MANAGEMENT AND POPULATION HEALTH (KREWSKI ET AL., 2007)*

- ***Policy/regulatory tools:*** Government policies, legislation, regulation, guidelines, permits, or approvals for required action
- ***Economic/financial tools:*** Insurance, levies and other cost structures, designed as incentives to take action
- ***Advisory/communications tools:*** Programs developed to encourage action, including communications, education, and awareness
- ***Community-based tools:*** In the case of the CCUS epistemic community, inception, support, and commitment to take action; may be volunteer-based. Also encompasses engagement with communities where CCUS projects are located
- ***Technological tools:*** Action through advances in technology

*We have lightly modified the REACT categories to better capture risk management options for CCUS.

Policy/Regulatory Measures

(1) ***Develop a national vision for CCUS in the context of Canadian climate policy.*** An interesting aspect of the CCUS enterprise emerged across the interviews: respondents did not suggest any risk management options under the sole purview of industry players. Participants perceived implementation as a joint government / industry climate change mitigation endeavour. This underscores the need for a national vision for CCUS in the context of Canadian climate policy (see below).

(2) ***Develop stable, detailed and coherent climate policy (notably carbon pricing).*** Canada needs detailed and coherent climate policy and GHG reduction plans to signal opportunities for investors, reduce policy risk and variability, and clarify the need for the technology. This includes carbon pricing, an economic/financial measure included below. Industry and individual company climate plans also need to be detailed and coherent.

(3) ***Increase intergovernmental policy collaboration to foster policy stability and reduce risk.*** Clear and stable climate policy and carbon pricing hinge on federal / provincial cooperation. Much of the industry still requires "green industrial development," which requires a shared vision among governments and industry. Federal provincial-cooperation in these areas is critical to moving the industry forward.

Economic/Financial Measures

(4) ***Use carbon pricing to provide economic incentives for CCUS.*** As a combined policy/regulatory measure, carbon pricing is a critical component of GHG reduction plans. Carbon prices need to be reasonable, predictable and robust, to provide adequate economic incentives for CCUS development. They will help achieve tolerable costs as well as create opportunities for venture capital and investment.

(5) ***Use cost sharing between government and industry to help move the technology forward.*** Cost sharing requires joint action between government policy and industry. When costs are shared, it further incentivizes industry to be creative, entrepreneurial, and successful.

Advisory/Communications Measures

(6) ***Broaden/deepen analysis of CCUS to demonstrate value.*** Detailed information that expands the assessment and understanding of CCUS can ultimately improve its prospects. This includes, notably, comparing various CCUS technologies to other mitigation options using lifecycle analysis.

(7) ***Improve understanding of CCUS technologies, approaches and uses across energy systems and industrial contexts.*** Policymakers and the general public need to be provided with information and education on CCUS more often and more effectively. This includes information on the use of CCUS in energy systems and broad-based mitigation efforts. For example, it is critical to broaden public understanding of the potential of the industry to reduce carbon intensity in operational contexts beyond fossil fuel use and production. This is important for public endorsement and social acceptance of CCUS, and in terms of fully exploring the scope of potential uses for CCUS technologies.

(8) ***Communicate cost improvements.*** Government and industry need to work together to clearly demonstrate and communicate progress on the economics of CCUS to policymakers, stakeholders, and the public.

(9) ***Increase knowledge-sharing and demonstrations in international export markets to increase opportunities for Canadian leadership.*** Reducing risks for the industry will also require knowledge sharing in international networks and demonstrations for export markets. If implemented to a greater degree, these activities are strengths for Canada, whose CCUS industry is more comprehensively developed than other nations. This type of knowledge-sharing can provide global opportunities in the arena in which Canada is a leader.

Community-based Measures

(10) ***Build transparent learning and engagement to generate trust.*** Perhaps most importantly, the recommendations above should be implemented based on transparent shared learning and engagement with all stakeholders and the general public. Lack of industry, stakeholder or public support (either for specific projects or the technology as a whole) can jeopardize the industry's forward movement.

Technological Measures

(11) ***Broaden the potential uses of CCUS, notably for 'hard to reach' sectors.*** Technology assessments should be broadened to explore more applications and storage options. For instance, expanding the analysis and development of storage strategies could help to demonstrate the potential value of various CCUS approaches to climate mitigation. Likewise, continuing to expand the understanding and potential of CCUS beyond fossil fuel contexts, such as applications in 'hard to reach' sectors like emissions-intensive and trade-exposed industries, will be key.

TABLE 4: RECOMMENDATIONS FOR POLICY, REGULATION AND LARGE INDUSTRY ACTIONS

Purview of action		
Government policy	**Government regulation**	**Large point-source industry**
Policy/regulatory options		
Develop a national vision for CCUS		
Climate change/GHG policy clarity/ certainty	Climate change / GHG regulatory clarity/ certainty	
Clear coherent climate change and GHG reduction plans		
Federal/provincial policy collaboration		
Economic/financial options		
Government / industry cost sharing		Government/industry cost sharing; industry cost reductions
Carbon pricing to create value proposition		
Information/Communications/Advisory options		
Information/education regarding CCUS, energy systems, mitigation alternatives		Information/education regarding CCUS, energy systems, mitigation alternatives
Cooperation and engagement in knowledge sharing, including international networks		Cooperation and engagement in knowledge sharing, including international networks
Government, industry and public analyze CCUS alongside alternative mitigation options		Government, industry and public analyze CCUS alongside alternative mitigation options
Continue to develop international networks		Continue to develop international networks
Community-based options		
Transparency and engagement in information / technological options		
Collaborative learning/engagement with public		
Technological options		
Broaden CCUS uses: expand storage strategies (CO2 destination point, monitoring)		
Broaden CCUS uses: relevance outside fossil applications		Broaden CCUS uses: relevance outside fossil applications
Government and industry demonstration for export market		Government and industry demonstration for export market

LOOKING FORWARD

CCUS will be an essential component of climate mitigation efforts in Canada and globally. Much additional analysis is required to identify how to best support CCUS technology development and deployment, including how to strengthen public confidence in decision-making and how to mitigate or avert polarization over CCUS technologies. Future research could include focused case studies of CCUS-related initiatives in other jurisdictions, such as 45Q in the United States or the *Clean Fuel Standard* in California. Likewise, research on how to develop trusted CCUS investment options for pension funds and institutional investors with sustainable investing goals would be valuable. Large tech companies (Microsoft, Shopify, Stripe, etc.) have invested in carbon removal funds that include CCUS. And most recently, Elon Musk has announced he plans to create a $100 million prize to support carbon capture technology development. Identifying the motivations driving support for particular technologies in these contexts will be important: whether or not CCUS is considered 'clean technology' in political, policy and investment terms will shape its future, as will perceptions of risks related to the technology.

Better understanding these issues will be essential to developing a national CCUS strategy for Canada that garners public confidence and support. It will also help to develop trusted investment indicators, such as those for Environmental, Social and Governance (ESG) investing, that will help to attract the capital needed to develop and deploy the technology.

Looking forward, it will also be important to better understand the motivations and concerns of potential opponents of CCUS, and to better assess whether there is common ground between proponents and detractors to address polarization over CCUS technologies and build public confidence in decision-making. This could include better understanding the views of those who oppose CCUS because of concerns for fossil fuel lock-in, or, alternately, better understanding the regional and local concerns of communities near CCUS infrastructure.

Advancing understanding in these areas, along with implementing the recommendations emerging from this study, will help to build public confidence in CCUS decision-making and position CCUS technology to make the contribution to climate mitigation envisioned for it over the past fifteen years. This is pivotal to successfully charting Canada's energy future in an age of climate change.

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APPENDICES

APPENDIX 1 - INTERVIEW PARTICIPANTS

Federal Government (Policy)

Frank Des Rosiers, Assistant Deputy Minister, Innovation and Energy Technology Sector, Natural Resources Canada
Jay Khosla, Assistant Deputy Minister, Energy Sector, Natural Resources Canada

Industry

Adam Auer, Vice-President, Environment and Sustainable Development, Cement Association of Canada
Francis Bradley, Chief Operating Officer, Canadian Electricity Association
Tim Eckel, Vice-President, Asset Management, Planning and Sustainability, SaskPower
Christie Gamble, Director, Marketing and Sustainability, CarbonCure Technologies
Evan Price, President and Chief Executive Officer, CO2 Solutions
Tim Wiwchar, Portfolio Business Opportunity Manager, Shell Canada

Research/Funders

John Adams, Managing Director, Natural Gas Innovation Fund
Russell Girard, Senior Manager, Screening and Evaluation, Sustainable Development Technology Canada
Candice Paton, Executive Director, Clean Technology, Carbon Capture and Utilization, Alberta Innovates

Nongovernment Research / Policy / Advocacy

Corwyn Bruce, Vice-President, Technical Services, International CCS Knowledge Centre
Sandra Odendahl, Former President and Chief Executive Officer, CMC Research Institutes
Jason Switzer, Former Managing Director, Industrial Decarbonization, Pembina Institute

APPENDIX 2 - INTERVIEW GUIDE

A. Carbon capture as an example of 'clean tech'

1. Generally speaking, if you had to describe initiatives that are 'clean technology' and relevant especially to energy transitions to lower emissions energy systems:

   a. What would be your qualifying criteria?
   b. Do you have any exclusions to what would qualify as 'clean tech'?

   Prompt for any known online guidance.

3. The term 'clean tech' can be used as it relates to carbon capture technologies. Does each of 1) carbon capture and sequestration (CCS), 2) carbon capture utilization and storage (CCUS), and 3) carbon conversion, meet the criteria of 'clean tech'?

   a. If so how, or why not?

   Prompt – Historical development
   - Vision for technological process started with a focus on geological sequestration (CCS) (IPCC 2005 Report)
   - Industry development was focused on CCUS – especially enhanced oil recovery
   - Other industries (such as cement) are researching and piloting carbon conversion, that is, to turn carbon emissions into new products.

B. Issues related to polarization or social acceptance that might affect decision-making to support or not support research, development, and implementation of CCUS technologies

2. With a focus on decision-making processes, please describe issues of polarization that could affect or have affected social acceptance for CCUS technologies

   Please note if you have experienced any of these and how the issue was addressed or not. Decision-making may be at the policy or project level.

   Another way to think about this is: What risk issues do you see that are related to decision-making or even the decision-makers themselves?

C. Risk management options for issues related to polarization or social acceptance of decision-making processes related to CCUS

3. To what extent is addressing issues identified in Question 3 (issues affecting social acceptance of decision-making processes/decision-makers) necessary for future implementation of CCUS options for large point-source emissions in Canada?

   Scale 1 2 3 4 5 6 7 8 9 10
   Not important Nice to do Absolutely critical

   What three risk issues in *decision-making processes* keep you up at night?

4. What risk management options might address these issues?

   For your top three concerns/areas for action in decision-making processes, what can be done about them?

Additional comments

5. Do you have any additional comments you would like to share?

Prompt – time permitting

For instance, do you have an international perspective for any of these issues and how they might be relevant in other parts of the world grappling with point-source emissions?

APPENDIX 3 - SELECTED STATEMENTS AND OBJECTIVES IN SUPPORT OF CCUS IN CLEAN ENERGY AND CLEAN TECHNOLOGY INITIATIVES

	Clean Energy	Clean Tech
International		
Clean Energy Ministerial (2019a)	Advancing Clean Energy Together – transition to clean energy economy; accelerating CCUS mitigation options will also contribute to other clean energy strategies	
IEA Sustainable Development Strategy (IEA, 2019e)	In the power sector, clean energy reflects decarbonizing and reducing emissions	In the industry and transformation sectors, GHG emission reductions through efficiency, aggressive innovation, and carbon capture
Canadian		
Pan-Canadian Framework for Clean Growth and Climate Change (2016)	Low carbon energy investments in electricity and clean energy, referring principally to renewables (wind/solar), but can be applied to oil, gas, coal	'Clean technology, innovation, and jobs' pillar includes industry's use of clean technology to improve energy efficiency and reduce carbon pollution
	Overall goals to capture CO2 emissions before they are released into the atmosphere	
Statistics Canada (2018)	Environmental and Clean Technology Products economic account includes any process, good, or service that reduces environmental impacts through: • Environmental protection activities that prevent, reduce, or eliminate pollution or any other degradation of the environment • Resource management activities that result in the more efficient use of natural resources, thus safeguarding against their depletion • The use of goods that have been adapted to be significantly less energy or resource intensive than the industry standard	

Generation Energy Council (2018)	• Cleaner upstream oil and gas extraction – develop and implement next generation CCUS • Clean power – a low-carbon industrial sector will rely (in near-term) on clean electricity and lower-carbon fuels	• CCUS could significantly reduce emissions at industrial sites in the longer term, with next generation of technologies implemented at a smaller scale and broader range of facilities, thus being more economically viable with current technology • More efficient use of energy end use captured CO2 as feedstock for value-added products
Federal government Clean Growth Program (2021)	$155M research, development and demonstration in energy, mining, and forestry sectors – includes carbon capture for the reduction of GHG and air-polluting emissions. In the 2019 intake, 28 Letters of Intent for carbon capture related projects were submitted, with 9 projects accepted as semi-finalists. Evaluation criteria included innovativeness, uptake potential, environmental impact, and economic and/or social impact	
Canada Energy Regulator Canada's Energy Future (2020)	The 2020 Energy Futures report is the first to extend the projection period to 2050. It also introduces the 'Evolving Scenario' as a complement to the usual baseline 'Reference Scenario'. The assumed 'Support for Clean Energy Technology and Infrastructure' includes CCUS development and deployment	
Private Sector		
Natural Gas Innovation Fund (2019)	$1.5M call for proposals for carbon capture projects for natural gas production	Capture system technologies for natural gas distribution, and advanced processes, materials, and equipment to improve efficiency and reduce cost
NRG – COSIA Xprize (2019)		$20M global competition for conversion of CO2 into products. Semi-finalist review criteria include CO2 uptake; the economic value of the product; product market size; and environmental footprint. Canadian companies are amongst the finalists

NOTES

POSITIVE ENERGY AT THE UNIVERSITY OF OTTAWA USES THE CONVENING POWER OF THE UNIVERSITY TO BRING TOGETHER ACADEMIC RESEARCHERS WITH EMERGING AND SENIOR DECISION-MAKERS FROM INDUSTRY, GOVERNMENT, INDIGENOUS COMMUNITIES, LOCAL COMMUNITIES AND ENVIRONMENTAL ORGANIZATIONS TO DETERMINE HOW TO STRENGTHEN PUBLIC CONFIDENCE IN ENERGY DECISION-MAKING.

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