CHAPTER 7

Carbon Capture, Utilization, and Storage: Public Confidence in Risk Decision-Making

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Introduction

Canada has developed extensive expertise and experience in point-source 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 or for enhanced oil recovery (EOR) operations. Carbon capture, transformation, and conversion, also under the umbrella of CCUS, is an important option for emissions-intensive and trade-exposed industries (EITE) such as cement, steel, and chemical manufacturing. In the

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last fifteen years, the CCUS industry has emerged as an important CO_2 mitigation option, but it has not reached its potential.

Despite Canadian expertise, and the fact that CCUS is a key component of many global emissions reductions scenarios (IPCC 2005; IEA 2019a), the technology faces challenges when it comes to public confidence in decision-making across a range of socioeconomic and political risk issues. This includes concerns for the adequacy of regulatory oversight and controversies over carbon issues more broadly. Technologies such as CCUS that extend or continue fossil fuel extraction or use can be controversial because of concerns over the degree of actual carbon reductions.

This study aims to identify and propose recommendations to mitigate the key risk issues driving public confidence in CCUS and government decision-making processes that govern and support it. The authors undertook a comprehensive review of academic, industry, and government publications, as well as in-depth interviews with decision-makers representing a variety of sectors involved in CCUS policy and implementation. Risk issues related to public confidence were categorized into thirteen categories identified in the risk management literature. Recommendations to mitigate the identified risk issues were developed using a slightly modified version of the REACT framework for risk management and population health (Krewski et al. 2007). The study suggests that a wide variety of risk management actions is needed in order for CCUS to make the contribution to climate mitigation that continues to be envisioned for large industrial sites.

The chapter proceeds in four sections. The first provides a primer on CCUS. The next delineates the research objectives, analytical approach, and methodology. The third section delves into the research findings, while the final section offers a discussion and recommendations for risk management.

A Primer on Carbon Capture, Utilization, and Storage

Carbon capture, utilization, and storage technologies may be applied to CO_2 emissions at point-source fossil energy electricity generation (coal, natural gas) and heavy industry sites (including oil and gas facilities). Demonstrated applications include carbon capture with saline aquifer sequestration (CCS) and carbon capture for enhanced oil recovery

(CCUS/EOR). Carbon capture and conversion in emissions-intensive and trade-exposed (EITE) industries focuses especially on cement, steel, and chemical manufacturing. Additionally, the term "CarbonTech" has been used to encompass all carbon capture technologies and technological processes that 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 chapter, unless CCS is highlighted specifically.

CCS and CCUS large-scale integrated projects (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% 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 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 CO_2 sequestration 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. 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.

There has instead been a propensity towards more CCUS/EOR projects (Larkin et al. 2019) 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 involving CO_2 sales was established in 2000 and was subject to a decade of biosphere and geosphere monitoring programmes (Bowden et al. 2013a, b).

With respect to the EITE sector, the current emphasis 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).

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. Despite this expertise, the technology still faces significant socioeconomic and political challenges and risks that we outline in the next section.

In terms of Canadian emissions, upstream oil and gas development is the country's largest source of GHG emissions, accounting for approximately 27% of emissions in 2017 and projected to grow to 32% by 2030 (Government of Canada 2019). Shell's Quest CCS project in Alberta, operating since 2015, is a 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, uses emissions from the North West Redwater Sturgeon refinery.

Electricity generation is Canada's fourth-largest source of GHG emissions (about 10%) and emissions are projected to decline to 4% of the total by 2030 (Government of Canada 2019). This is primarily due to 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.

With respect to the application of CCUS for heavy industry outside oil and gas production, this is another area with strong potential. Approximately 11% of GHG emissions originated from heavy industry in 2017 and emissions are projected to grow to approximately 13% by 2030 (Government of Canada 2019). The IEA (2019b) suggests that emissions reductions in iron and steel, cement, aluminium, and chemical industries remain particularly difficult. Alberta's Carbon Trunk Line, noted above, uses CO_2 sourced in part from the Nutrien fertilizer plant. Carbon conversion may be applied to a greater extent for the EITE sector, as demonstrated by the cement industry (Carbon Cure 2021). Canada's existing large-scale projects (Shell Quest, Boundary Dam and Alberta Carbon Trunk Line/North West Refiner/Nutrien) could eliminate up to 4 megatons of CO_2 equivalent per year or 6% of Canada's emissions reductions through 2030 (Larkin et al. 2021).

Research Objectives, Analytical Approach, and Methodology

This study focuses primarily on decision-making processes for CCUS technologies. As noted previously, for over 15 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). And yet, the technology has not been deployed as rapidly as envisioned. This study aims to help understand why, with a specific focus on identifying the key risk issues driving public confidence (or lack thereof) in CCUS and government decision-making processes that govern and support it.

We use the term public confidence broadly to indicate the overall support and comfort that the public and private sector actors like investors have for a given energy system and its associated regulatory scheme. A key aspect of public confidence is social acceptance. When it comes to energy transition technologies like CCUS, social acceptance has become one of the most policy-relevant concerns (Upham et al. 2015; Gaede and Rowlands 2018). 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. A second important issue is that societal responses are not static: stakeholders' views and innovation contexts evolve throughout the public policy cycle (Busse and Siebert 2018). For example, at the level of individual projects, local context matters a great deal (i.e., for communities adjacent to facilities). Alternately, social acceptance can also manifest at the national level, with a focus on a particular technology in the context of national policymaking and goals. 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).

The challenges of public confidence and social acceptance exist within a broader context of other factors described by Cleland and Gattinger (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.

We use a risk-based framework for the analysis (Rothstein et al. 2013). Risk assessment and risk management (RA/RM) have been applied for decades to health and environmental protection and public safety, as well as to 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.

The risk issues selected for analysis build on 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 (see Table 7.1). The first category (seven risks) comprises ***cross-cutting*** factors for all stakeholders (government, industry, and the public): worldviews, problem perception, trust, energy context, knowledge/information provision, tolerable costs, and distributive justice. The second category relates to ***governance*** factors (three risks): policy and regulatory stability, inter-jurisdictional challenges, and procedural justice. The third category focuses on ***industry*** factors (three risks): willingness and/or capacity to act, pace/demonstration of technological feasibility, and market competitiveness/international trade. Each of these issues is described in the following section of the chapter.

The study's analysis draws on academic literature and government documents, as well as fourteen interviews with decision-makers that have

Table 7.1 Risk issues related to public confidence in decision-making for CCUS

Risk issue	*Definition*
1. Cross-cutting factors for government, industry, public	
*Worldviews (10)	The sets of assumptions, beliefs, and experiences that inform attitudes (stakeholders, public, etc.) 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 outlay to implement and maintain a project
*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

Notes in table (#) represents how many of the fourteen interview participants mentioned the risk issue. *Issues marked with an asterisk emerged as higher risk issues (more than half of interview participants mentioned them). List of risk issues adapted from Leiss and Krewski (2019) and L'Orange Seigo et al. (2014)

varying degrees of shared interests in advancing carbon capture mitigation options and outcomes. Within this CCUS 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 industry advocacy NGOs.

Scholars characterize this kind of network as an "epistemic community" or knowledge-based network of recognized experts. Members of these networks 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).

Semi-structured interviews were undertaken 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").

Research Findings: Public Confidence Risks Related to CCUS Decision-Making

Risk issues related to CCUS occur 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 and electricity generation (our study's focus), as well as transmission, transportation, the built environment, agriculture, forestry, waste, and government operations (Specific Mitigation Opportunities Working Group 2016).

As shown in Table 7.1 and detailed below, nine of the thirteen risk issues noted above were mentioned by more than half of participants. We categorize these as “higher risk” issues. Of note, with the exception of trust, all *cross-cutting* risk issues were mentioned more frequently.

The three risk areas mentioned by the largest number of interviewees (12 of 14) include:

(i) inadequate knowledge and information provision,
(ii) the need to reduce costs, and
(iii) inadequate pace of effective project demonstration.

As explained below, participants noted that CCUS is vulnerable in a public and decision-maker context marked by inadequate awareness and understanding of the industry and the broader energy system. Costs (and by extension financial support) were noted as a key concern, especially in terms of being able to make CCUS technologies cost-effective enough for wide-spread implementation. Finally, interviewees noted that 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.

Cross-Cutting Factors for Government, Industry, the Public

Worldviews (higher risk: mentioned in 10 of 14 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 (assumptions, beliefs, and experiences that inform attitudes) 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 supported 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 CCUS acceptance because it is seen to perpetuate fossil fuel production and use and is perceived to represent unacceptable risks to the environment. As one interviewee noted, "[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."

Participants agreed that a variety of actions, such as information provision and a focus on CCUS as part of the solution to climate change, particularly for hard to reach sectors, would be most likely to help lessen this challenge. In the words of one participant, "Canada can […] 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." Other suggestions included developing a common GHG reduction vision in Canada and demonstrating the technology's relevance beyond conventional fossil fuel applications such as EOR.

Problem perception (higher risk: mentioned in 11 of 14 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.

Transition expectations can fundamentally affect perceptions of CCUS as a solution or a problem. For example, previous research has identified two expectations for energy transition among the general public and among energy and environmental leaders in Canada: one focused on a gradual process of change, and the other focused on aggressive emissions reductions (Beck 2020; Bird et al. 2019). Survey research reveals that 73% of Canadians expect at least a moderate pace of reducing GHG emissions with expectations for substantive change in 25 years or less. Within that group, 43% prefers a more aggressive pace of 10 years or less (Bird et al. 2019). A small minority (27%) prefers a much slower pace of 50 years or longer. These differences in views can dramatically shape perceptions of CCUS.

As noted earlier, CCS scholarship has found CCUS/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 technological options to abate emissions. In the EITE sector, differences in problem perception may be muted because the question of carbon storage includes the potential for conversion into a resource (rather than storage as a waste or increasing fossil fuel production).

Key suggestions to manage 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 help to address the risk posed by differences in problem perception.

Energy context alternatives (higher risk: mentioned in 10 of 14 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 (Nourallah 2016; Cleland and Gattinger 2017).

Participants in this study noted that CCUS has the potential to achieve multi-billion dollar markets internationally, but it is challenged by competition from increasingly affordable natural gas, wind, and solar energy 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 with 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. As one interviewee noted, "[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."

Lack of trust (lower risk: mentioned in 5 of 14 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. 2016, 2018; Nourallah 2016), including for CCS (Einsiedel et al. 2013). This is due in part to levels of trust in new technologies; communities can be sceptical 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. In addition, they suggested that policy longevity and stability are essential to promote trust in government, particularly industry trust in government. Industry participants also noted that individual actions by their own sector could undermine trust in the entire CCUS endeavour. In the words of one participant, "[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?'".

Tolerable costs (higher risk: mentioned in 12 of 14 interviews). Concerns over cost emerged as one of the most important risk issues for all participants, but they took 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 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 2020). In this study, participants also noted that variations in government funding between jurisdictions can have different regional cost/benefit impacts. Further, participants noted 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 programmes of public support through tax incentives, supportive policy, and research support via effective demonstration and pilot projects.

Inadequate knowledge/information provision (higher risk: mentioned in 12 of 14 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 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), regulatory leaders, and environmental stakeholders. Participant concerns mainly focused on the degree of knowledge about market risks, challenges, and specific attributes of the technology. One participant noted, "[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."

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

Distributive justice (higher risk: mentioned in 11 of 14 interviews). This issue encompasses policy and project decision-making that involves tradeoffs 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 the 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

Lack of policy and regulatory stability (lower risk: mentioned in 7 of 14 interviews). Policy and regulatory stability for GHG emissions reductions can affect support (directly or indirectly) for CCUS implementation. While consistent policies for CCUS mitigation technologies are important, 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, participants noted that it increases mistrust and risk, and weakens the investment climate. Interviewees 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. In the words of one interviewee, "Stable climate change policy: people are hungry for it."

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, research and development, and investment.

Inter-jurisdictional challenges (higher risk: mentioned in 9 of 14 interviews). This risk issue concerns decision-making that involves two or more jurisdictions. 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 unabated coal-fired power by 2030. There are misalignments between provinces as well. 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 levels. As noted by one interviewee, "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."[1] Industry participants also worried that government consultation

[1] The Supreme Court of Canada decision affirming the constitutionality of federal carbon pricing legislation followed the interview research.

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.[2]

Procedural justice (lower risk: mentioned in 5 of 14 interviews). Risk issues related to procedural justice are focused on decision-making processes, including policy and regulatory decision-making that is transparent, engaged, and accountable. 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. 2016; Simard 2018; Frank and Lindsay 2020). 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. According to one interviewee, "[It is important to] 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."

Interviewees also noted that in some parts of Canada 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 the 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 programmes.

[2] For a review of energy-environment federalism in Canada, see Bratt (2021).

Industry Factors

Willingness/capacity to act (higher risk: mentioned in 10 of 14 interviews). This emerged as a relatively important risk issue and refers to the tension between industry actors that are able and willing to move forward on technology implementation and those that are not. Tension can be heightened by public perceptions that industry is lagging when it comes to vigorously moving forward with a clear commitment to finding emissions abatement solutions. 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.

Pace and demonstration of technological feasibility (higher risk: mentioned in 12 of 14 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 slow grind. Several participants raised the importance of scaling up the technology to a level that has a meaningful emissions impact.

Participants noted that 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 7 of 14 interviews). This area was one of the few bright spots for participants, who characterized it as a strength. Government documents and interviewees emphasized 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. 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.

The following section categorizes participant recommendations to mitigate the above-noted risks using the REACT framework of risk assessment and risk management.

Discussion, Conclusion, and Risk Management Options Emerging from the Research

The nations that lead in policy and project support for CCUS include Canada, the United States, Norway, the United Kingdom, and Australia. Other nations score lower on a 2021 "readiness index" (GCCSI 2022). Overall, however, global implementation of CCUS is not on track to meet mitigation projections (IEA 2019c). Specifically with respect to CCS, a variety of reasons explain limited progress. These are generally identified as technical, economic, political-institutional, social, and international (Viebahn and Chappin 2018; Markusson et al. 2017; Gaede and Meadowcroft 2016). Many of the challenges facing CCS and CCUS are not unique to Canada.

But who should do what and how to address this? We apply a lightly modified version of the REACT framework for risk management and population health (Krewski et al. 2007, 2014). We use REACT to categorize the various approaches and tools participants recommended and highlighted for each risk issue discussed above (see Table 7.2). These fall under the purview of policymakers, regulators, and industry, often working in concert.

Policy/regulatory options involve government policy, legislation, regulations, guidelines, permits, or approvals for action. Interestingly, participants did not suggest any risk management options under the sole purview of industry players. They viewed implementation as a joint government/industry climate change mitigation endeavour, which suggests the need for a national vision for CCUS in the context of Canadian climate policy. Further, participants underscored the need for

Table 7.2 Risk management options for policymakers, regulators, and industry

Purview of action		
Policy	*Regulation*	*Large point-source industry*
	Policy/regulatory options	
Policy clarity and certainty for climate change/GHG	Develop a national vision for CCUS	
	Regulatory clarity and certainty for climate change/GHG	
	Clear and coherent climate change and GHG reduction plans	
Federal/provincial policy and regulatory collaboration	Federal/provincial policy and regulatory collaboration	
	Economic/financial options	
Government/industry cost sharing	Carbon pricing to create value proposition	Government/industry cost sharing; *plus* industry cost reductions
	Advisory/communications options	
Information/education regarding CCUS, energy systems, mitigation alternatives	Government, industry and public analyse CCUS alongside alternative mitigation options	Information/education regarding CCUS, energy systems, mitigation alternatives
Increased development of international networks		Increased development of international networks
Cooperation and engagement in knowledge sharing, including international networks		Cooperation and engagement in knowledge sharing, including international networks
	Community-based options	
	Transparency and engagement in information/ technological options	
	Collaborative learning/engagement with the public	
	Technological options	
	Broaden CCUS uses beyond fossil applications	

(continued)

Table 7.2 (continued)

Purview of action		
Policy	*Regulation*	*Large point-source industry*
Expand storage strategies (CO_2 destination point, monitoring)		
Government and industry demonstration for export market		Government and industry demonstration for export market

Source Authors' own source

stable, 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 discussed below. Interviewees noted that industry and individual company climate plans also need to be detailed and coherent. In addition, participants noted that clear and stable climate policy and carbon pricing hinge on federal/provincial cooperation to foster policy stability and reduce risk. Much of the industry still requires "green industrial development," which requires a shared vision among governments and industry.

Economic/financial tools refer to insurance, levies, and other cost structures designed as incentives to take action. Interviewees emphasized that carbon pricing is a critical component for CCUS to help achieve tolerable costs as well as create opportunities for venture capital and investment. Carbon prices need to be reasonable, predictable, and robust to provide adequate economic incentives for CCUS development. Participants also recommended using cost sharing between government and industry to further encourage industry to be creative, entrepreneurial, and successful. In the period since the interviews were undertaken, the US has extended its 45Q carbon sequestration tax incentive programme (US Code 2022) and the Government of Canada has initiated creation of a CCUS investment tax credit (Government of Canada 2022b).

Advisory/communications tools encompass communications, education, and awareness activities. Participants recommended deepening and broadening the analysis of CCUS to demonstrate potential value. This could include, notably, comparing various CCUS technologies to other mitigation options using lifecycle analysis. Similarly, interviewees noted the importance of improving understanding of CCUS technologies, approaches, and uses across energy systems and industrial contexts. They suggested providing policymakers and the general public with information and education on CCUS more often and more effectively. This would include, critically, the potential of CCUS to reduce carbon intensity in operational contexts beyond fossil fuel use and production. They likewise proposed better communication of cost improvements to clearly demonstrate and communicate progress on the economics of CCUS to policymakers, stakeholders, and the public. Finally, they suggested increasing knowledge sharing and demonstrations in international export markets to increase opportunities for Canadian leadership.

Community-based tools range from those targeting the CCUS industrial ecosystem to engagement with communities where CCUS projects are located. Here, interviewees noted the importance of building transparent learning and engagement with all stakeholders and the general public to foster public confidence in the technology and decisions surrounding it.

Technological tools refer to advances in technology. The key recommendation here was to broaden the potential uses of CCUS, notably for EITE industries. Interviewees noted that technology assessments should be broadened to explore more potential uses across all energy systems and industry contexts.

CCUS is and will be an essential component of climate mitigation efforts in Canada and globally. As noted above, the Canadian and US federal governments have announced additional investment tax credit proposals for sequestration projects (Government of Canada 2022a; US Code 2022), and Canada has announced grants and contributions for technology development (Government of Canada 2022b). However, 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. Looking forward, it will also be important to better understand the motivations and concerns of potential opponents to CCUS, and to better assess whether there is common ground between proponents and detractors to 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. This research suggests that 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.

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