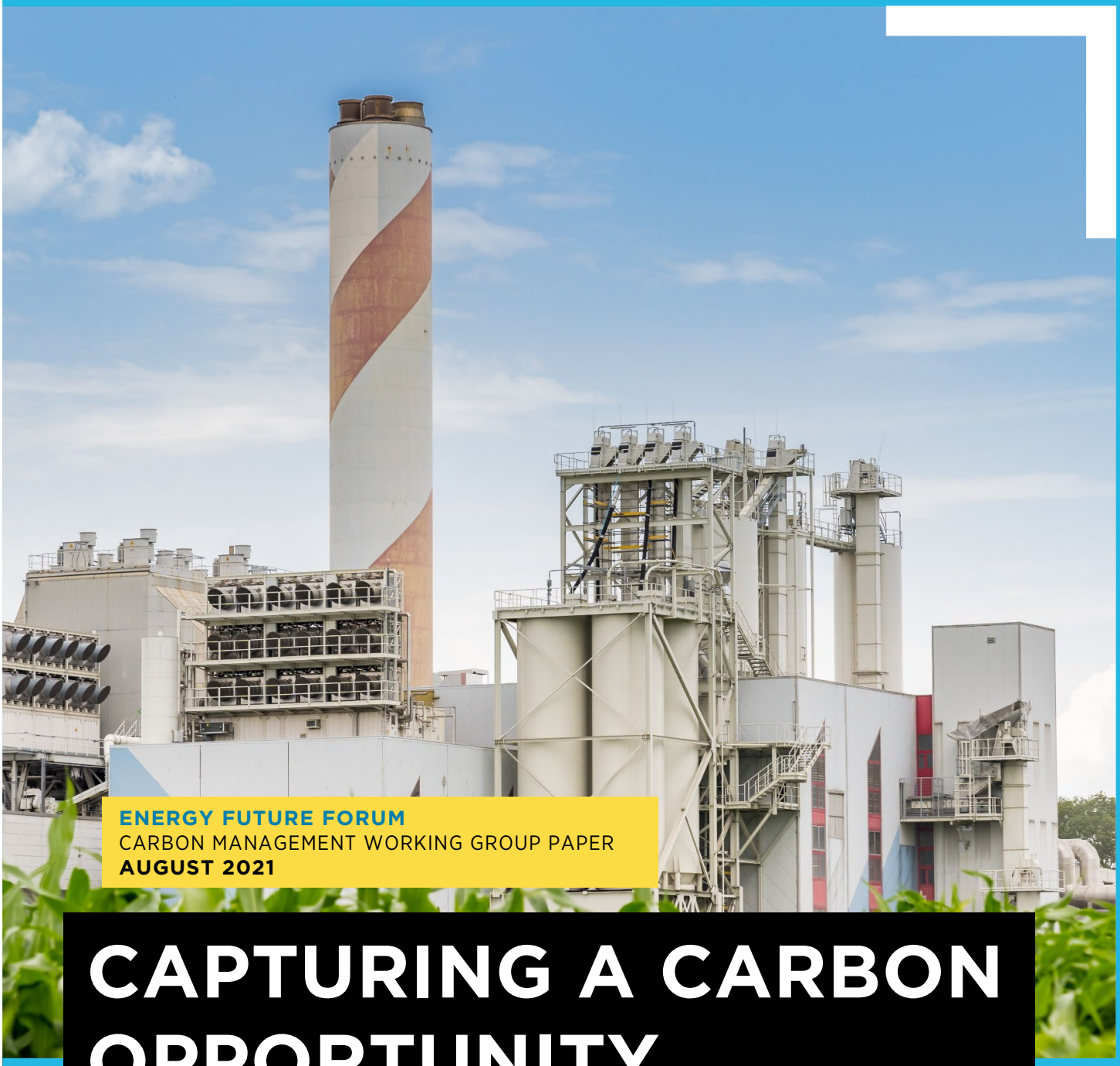

ENERGY FUTURE FORUM
CARBON MANAGEMENT WORKING GROUP PAPER
AUGUST 2021

CAPTURING A CARBON OPPORTUNITY

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ABOUT THE PROJECT

The Energy Future Forum is a pan-Canadian and multi-year initiative that is working to address climate action and our energy future around one table. Its mission is to develop practical measures that help Canada meet or exceed our 2030 emissions targets on the way to a net zero future, and that strengthen an innovative economy, deepen shared prosperity and enhance national unity. The Forum includes leaders from business and government, along with academic, environmental and Indigenous organizations, comprising participants from five regions. The Forum is determined to see this collaborative effort map out an ambitious set of actions that are environmentally sound, economically beneficial and publicly acceptable.

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EXECUTIVE SUMMARY

The climate and economic challenge Canada faces is clear – and daunting. Meeting the stated federal objectives of a 40 to 45 percent reduction from 2005 GHG emissions levels by 2030 – on the way to a net zero future by 2050 – means removing at least 300 million tonnes of carbon from the economy in less than nine years. Ideally, this needs to be done in a way that not only maintains economic growth, but also generates additional growth and prosperity for Canadians. That's no easy feat.

In this paper, we argue that an essential part of Canada's climate and economic plan should be a national carbon management strategy that captures CO2 emissions from point sources and also removes carbon from the ambient air. If Canada plays its cards right, we could be home to a booming carbon capture and removal industry in the coming decades, one that both contributes to decarbonizing our economy and generating significant new opportunities.

Carbon management is any activity that captures carbon, stores carbon or connects the capture and storage of carbon. It includes a diverse range of engineered activities. They include carbon capture, utilization and sequestration (CCUS) from specific industrial sources, carbon dioxide removal through direct air capture or mineralization and the sequestration of carbon in building materials such as cement. Another form involves nature-based solutions, where the natural environment is used to reduce CO2 in the ambient air. This paper, a product of the Energy Future Forum's Carbon Management Working Group, focuses its attention on engineered carbon management, as opposed to nature-based solutions.

Carbon management is only one part of a comprehensive decarbonization strategy (it is equally important to aggressively pursue other forms of mitigation), but it is a critical part of the climate toolkit. In its recent special report setting out a pathway to net zero by 2050, the International Energy Agency identifies carbon capture as one of five key pillars to decarbonization. The UN's Intergovernmental Panel on Climate Change agrees, as does the National Academies of Science. Both state that CO2 removal is essential to all pathways that would limit global temperature increases to 1.5 degrees Celsius.

Carbon management is critical for at least three related reasons:

- First, carbon capture is key to reducing emissions from point sources, especially sources like cement production where few alternatives exist.
- Second, negative emissions through technologies like direct air capture will be important to offset non-point sources like agricultural emissions, which are difficult to tackle directly.
- Third, negative emissions will be key even after the world reaches net zero to help reduce atmospheric levels of carbon dioxide.

Canada has all the ingredients to establish its position as a major player in the carbon management space, but we cannot rest on our laurels. Among Canada's assets are a world-leading collection of new and established companies with engineering expertise and capabilities, along with established regulations and a series of natural endowments. Look at most components of the future carbon management industry and you will see Canadian companies in leading global positions. Although Canada may have had an early start on CCUS, and shows great potential for future growth, bold policy moves in the United States and Europe mean our leadership position is at risk if more action does not come soon.

If carbon management is to meet its potential, it must become a climate solution that is also a business opportunity with a clear revenue stream. Today in Canada, carbon capture is too often seen only as a cost and not as an investment opportunity. In the pages that follow, we methodically describe the components of an emerging industry where costs are declining, revenue potential is emerging, and many players are entering a high-potential market.

As with most early-stage industries, public policy support will be critical, especially to generate early revenue streams that can accelerate scale up. Federal and provincial governments have taken encouraging steps in the right direction. Carbon pricing, for example, can act as a powerful incentive for businesses to invest in carbon management. The use of direct government financial support to help cover the upfront capital investment of carbon capture projects, which has been particularly evident in Europe and in some early Canadian projects, may also prove important as the Government of Canada advances on its proposed Investment Tax Credit for CCUS.

In the coming weeks, the Energy Future Forum's Carbon Management Working Group will turn its attention to how Canada can adopt the right package of policies to enable the carbon management sector to reach its potential in helping Canada drive emissions reductions and economic growth.

INTRODUCTION

In the coming years, Canada faces a large and urgent challenge. As part of the global effort to address climate change, the Government of Canada has committed by 2030 to reduce our nation's GHG emissions by 40 to 45 percent below 2005 levels, with the ultimate goal of reaching net zero emissions by 2050 or sooner. The net-zero goal is certainly ambitious – equivalent to slashing emissions by the amounts recorded during the height of the COVID-19 pandemic each and every year from now through 2050. And even if we achieve net zero, Canada – and the world – will ultimately need to become carbon negative, which means pulling carbon from the air to reduce existing atmospheric concentration levels.

For an energy-exporting nation like Canada, with a widely dispersed population residing in northern climates, meeting our climate change goals requires that we pursue all pathways. Not only must all sectors of the economy and society be engaged in reducing CO2 emissions, but we need to pursue decarbonization in a way that also contributes to a strong economy by replacing longstanding drivers of growth and exports. Canada needs a national strategy that aggressively reduces GHG emissions, incorporates existing sectors and creates new industries in the transition.

Carbon management – a set of activities that captures carbon and then sequesters or utilizes it – is indispensable to enabling Canada to meet its emissions targets while generating significant new economic activity across the country.[1] It can build on existing strengths and competitive advantages in managing carbon safely and in kickstarting the country's enormous hydrogen energy potential. But we must move quickly and purposefully to keep up – or, ideally, get ahead – of other countries pursuing the same opportunity. The essence of this paper is that Canada has a good start. We have a world-leading collection of new and established companies with engineering expertise and capabilities, established regulations and a series of natural endowments, including a globally-leading energy industry of the past century. However, although Canada may have had an early start on carbon capture, utilization and storage (CCUS), bold policy moves in the United States and Europe mean our leadership position is at risk if more action does not come soon.

Canada can look to carbon management in two ways: either as a cost to be borne – as with all infrastructure, there will certainly be a requirement for public investments – or as a promising win-win opportunity that reduces emissions and launches new economic growth at the same time. A series of recent announcements around carbon capture and hydrogen projects underscores the extent of the potential to enter the energy transition with new cleantech drivers of growth, jobs and exports – key ingredients for a truly just transition.

[1] As explained below, we use the term carbon management to include a wide set of potential capture activities that extend beyond traditional point-source carbon capture to also include engineered forms of carbon dioxide removal, pyrolysis, biological solutions and more. Others may use the terms CCS or CCUS to encompass most or all of what we refer to here.

While the entire industry has potential, different applications of carbon management are not all comparable with regard to their current technological readiness or commercial viability. Some applications, such as natural gas processing, fertilizer, ethanol and hydrogen production at refineries have multiple established projects and a clear economic pathway to further scale up with targeted policy support. Other applications – for example, direct carbon capture from the surrounding ambient air – are in the pilot or development stage and will require greater policy support to enable new projects and bring them down the cost curve.

For the potential of a carbon management strategy to be fully realized, it must be applied broadly across multiple economic sectors in all regions of Canada. After all, carbon management goes well beyond the energy sector, with potential to apply to a wide number of industrial sites and activities that emit significant levels of CO2 emissions, including cement and steel production, mining, fertilizers and petrochemicals.

Of course, the pursuit of carbon management opportunities must be done in tandem with an ambitious effort to mitigate emissions through other tools such as renewable energy, energy efficiency and more. Carbon management is a key tool but must fit within a comprehensive strategy to reach net zero.[2]

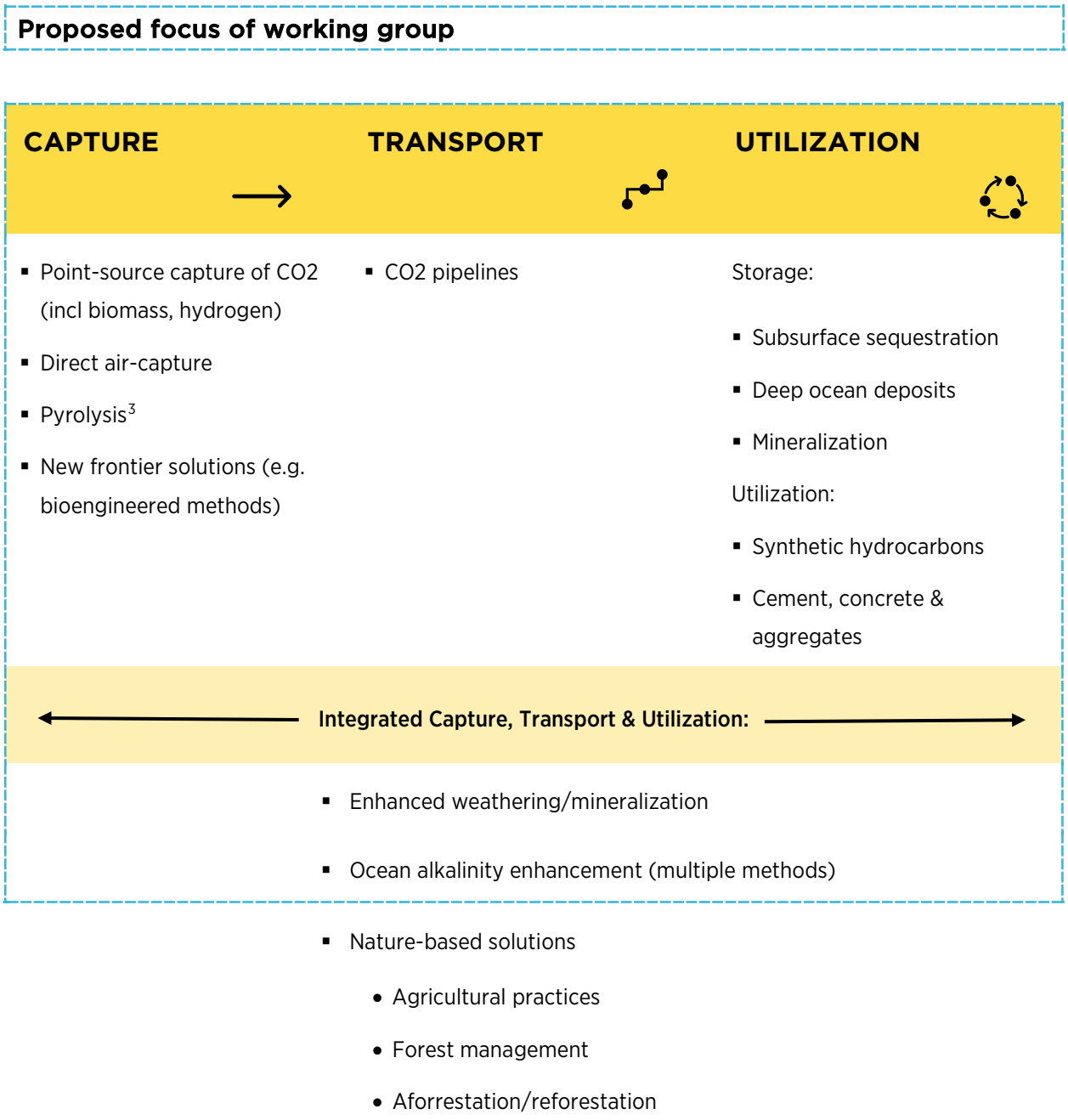
In this paper, we will catalogue some of the companies and initiatives that are showing the way. The stirrings of an innovative ecosystem are apparent – one that features elements that range from finance and research to the collection, transport, storage and utilization of carbon and hydrogen. The intention of the Energy Future Forum's carbon management working group is to catapult this nascent industry into the top global ranks through strategic policies by governments that work hand-in-hand with industry know-how.

WHAT IS CARBON MANAGEMENT?

A wide range of activities could be categorized as carbon management. In fact, the term itself is still fairly new. We define carbon management as any activity that captures carbon, stores carbon or helps connect the capture and storage of carbon. Figure 1 offers a visual schematic of key activities that would be considered part of the carbon management space:

[2] Carbon management investments should also be made with long-term decarbonization goals in mind. It would be undesirable to have carbon management investments in the near-term crowd out direct mitigation opportunities through alternatives like electrification or green hydrogen that might be available in the medium term.

Figure 1: A schematic of carbon management activities



As Figure 1 illustrates, carbon management spans a diverse range of activities. It includes carbon capture utilization and sequestration (CCUS) from point sources, carbon dioxide removal through processes such as direct air capture, carbon sequestration in building materials such as cement, and nature-based solutions

[3] Pyrolysis is the heating of an organic material, such as biomass, in the absence of oxygen. Rather than combust, the chemical compounds thermally decompose into combustible gases and charcoal.

that use the absorption capacity of nature to remove CO2 from the ambient air. It also involves emerging solutions such as enhanced weathering, increased ocean productivity and bio-oils. Together, there is a large potential industry with clear synergies across activities and an opportunity to nurture an exciting climate and economic opportunity.

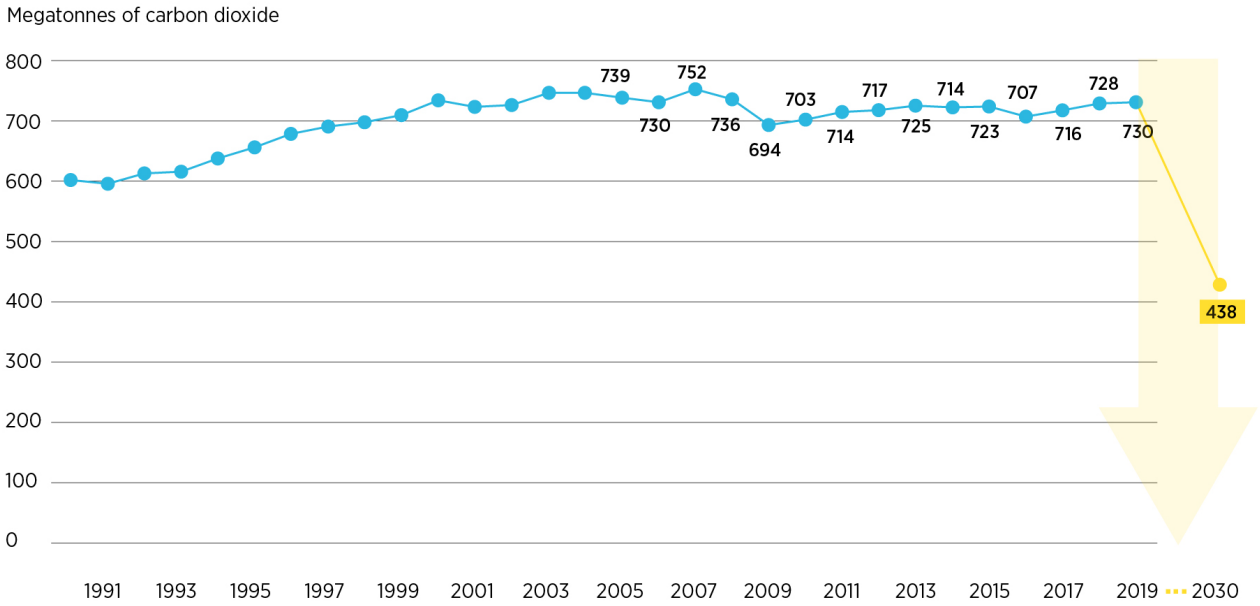
The Energy Future Forum's Carbon Management working group will focus most of our attention on engineered opportunities, as opposed to the nature-based solutions listed in Figure 1. While nature-based sequestration has a role as a climate solution (not to mention many other environmental benefits), our focus is in areas where we need to make significant private and public financial investments as a country to capture the economic opportunity that might otherwise go to foreign competitors, and in areas where carbon sequestration is more durable. In addition, the potential for scaling up nature-based solutions has been profiled in a previous Energy Future Forum paper, Nature-based Solutions – Some of the Answers to Climate Change Come Naturally.

We discuss the carbon management industry as a whole for much of this paper because we believe that policymakers across the country should be considering how to develop the entire sector. But we also want to be clear that the industry is far from homogenous. Some potential projects involve more mature technology and attractive economics and will thus be ready to scale up sooner. In general, point sources with more pure forms of CO2 or higher pressure gas streams, such as fertilizer plants, natural gas processing and hydrogen upgrading, will have more attractive economics. In contrast, technologies that remove carbon from the ambient air are more costly and less technologically mature, especially newer non-direct air capture technologies. The use of captured carbon is also a key consideration for projects. Sequestering carbon underground is relatively expensive but maximizes the CO2 reduction, whereas selling the CO2 for commercial use, such as enhanced oil recovery, increases the potential profitability of a project but could lead to less CO2 impact. We further elaborate on the cost differentials across industries, technologies and other project characteristics later in this paper.

WHY DO WE NEED CARBON MANAGEMENT?

To put the climate challenge into context, virtually every year for the past decade, emissions have gone up in Canada. We are the only G7 nation whose emissions have risen since the Paris climate agreement was signed in 2015. We must now, in less time, not only reverse that trend, but also see it dramatically plummet if we are to meet our commitments. That means that in fewer than nine years, Canada's emissions must fall from current annual levels of approximately 730 megatonnes (Mt) to 438 Mt – a drop of nearly 300 Mt. With demand and consumption for energy in Canada hard to decouple from economic activity and our quality of life, decarbonization must be pursued in a way that creates economic opportunity and growth, ensuring as smooth a transition as possible for individuals and for communities heavily reliant on the traditional energy sector.

Figure 2: Greenhouse gas emissions in Canada, 1990 to 2019



Source: Environment and Climate Change Canada

For multiple reasons, there can be little doubt that carbon management is integral to meeting climate goals.

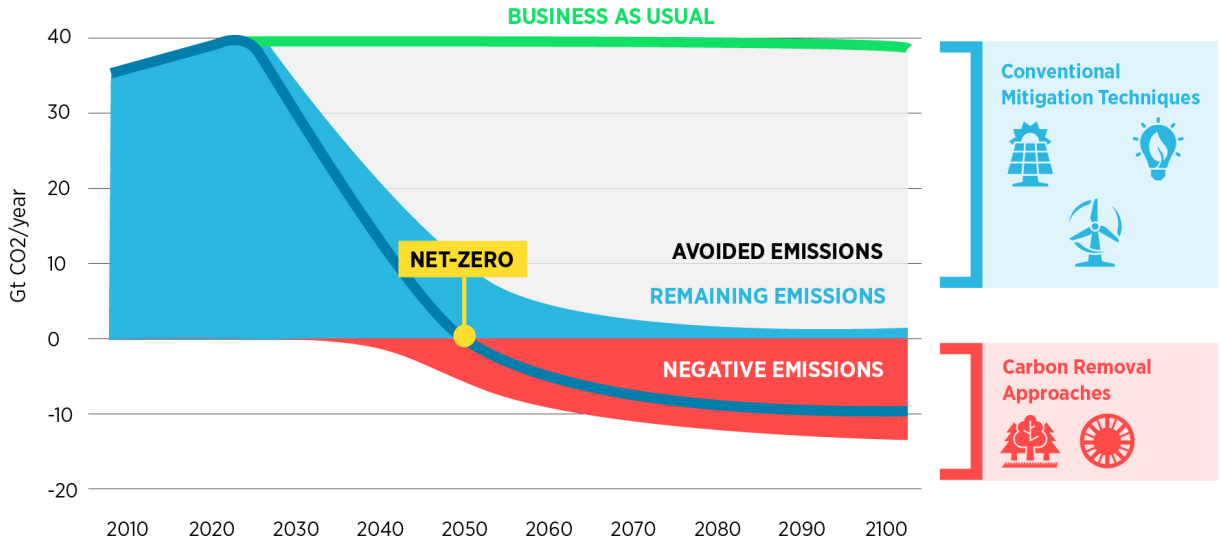
First, CCUS is a critical part of reducing existing emissions from point-sources such as cement factories, oil refineries, natural gas power generation and other industrial facilities and processes. That's among the reasons why CCUS features prominently in the International Energy Agency's (IEA) recent special report setting out a pathway to net zero by 2050. The report identifies carbon capture as one of the five key pillars to decarbonization, and it suggests there could be 6.6 gigatonnes (Gt) of point-source CCUS globally by 2050. It notes that carbon capture facilitates the transition to net zero "by tackling emissions from existing assets, providing a way to address emissions from some of the most challenging sectors; providing a cost-effective pathway to scale up low-carbon hydrogen production rapidly; and allowing for CO2 removal from the atmosphere BECCS (bioenergy equipped with carbon capture and storage) and DACCS (direct air capture with carbon capture and storage)".

Second, carbon dioxide removal is needed to offset certain emissions that are too diffuse to be addressed through carbon capture and storage. For example, long-haul aviation is currently incredibly expensive to decarbonize with zero-carbon fuels, a fact that is leading some airlines to consider offsetting their emissions through negative emissions technologies, such as direct air capture, as a more cost-effective approach. Yet other emissions, such as the nitrous oxide from fertilizer use or the methane that comes from cattle, can be reduced but are very hard to eliminate directly. There again, negative emissions technologies may be the best option.

Third, even if we reduce all existing emissions and reach carbon neutrality, there will almost surely be a need to use carbon dioxide removal technologies to reduce the amount of carbon in the atmosphere. That's because the safe amount of total carbon we can put into the atmosphere is quickly disappearing – by some estimates, we have less than eight years of global emissions left before we will cross a climate red line, locking in more than 1.5°C of warming. If history is any guide, there is a very strong likelihood we will exceed our global carbon budget and thus will be compelled to draw down carbon from the atmosphere to compensate. The National Academy of Sciences has estimated we will need to sequester 10 Gt per year by 2050, rising to 20 Gt by 2100.

The world's largest body of scientific experts on climate, the Intergovernmental Panel on Climate Change (IPCC), agrees that carbon dioxide removal will be a critical component of decarbonization. In its 2018 report, the IPCC clearly stated that all pathways to maintaining global temperature rises below 1.5°C require carbon dioxide removal (see Figure 3). In a 2018 report, the US-based National Academies of Science similarly argued that negative emissions technologies (NETs) – in particular direct air capture – are crucial to achieving the twin objectives of climate stability and economic growth. "NETs that remove and sequester carbon dioxide from the air will need to play a significant role in mitigating climate change."

Figure 3: Pathways to 1.5°C - Staying below 1.5 Degrees of Global Warming



Source: Adapted from IPCC 2018. World Resources Institute.

There are those who fear that putting resources, whether public or private, into engineered carbon management practices will delay decarbonization because it will perpetuate the use of fossil fuels. We don't see things that way for several reasons. First, some emissions sources – such as emissions from the process of producing cement and other industrial products – have few viable solutions other than carbon capture and storage. Second, carbon dioxide removal will be needed even after we meet net zero, so it makes sense to begin scaling up the industry now. Third, fossil fuels are likely to remain a meaningful, if declining, source of energy for years to come. For example, the IEA has produced a net zero by 2050 scenario in which fossil fuels fall from the current level of almost four-fifths of total energy demand to slightly over one-fifth by 2050.

This raises important and fundamental questions: Shouldn't we seek to capture emissions during the transition to renewable energy? Shouldn't we at least hedge our bets, given what is at stake? Shouldn't we seek to advance technology in Canada that can be deployed at scale globally to address the international problem of decarbonization? Carbon capture and storage can often be a lower-cost way to address emissions than relying solely on other forms of mitigation or stranding existing assets. The IEA estimates that a scenario with more limited use of carbon capture and storage could make the transition to net zero USD$4 trillion more expensive for hard-to-abate sectors. This is particularly important in places like the Prairies, where the path to decarbonization risks significant strain on the economy, jobs and livelihoods given the economic importance of fossil fuels in those economies. Carbon management can help Canada reach its climate goals while mitigating some of the negative economic consequences, ushering in a new growing economic sector and strengthening national unity. And it must do all that while being matched with an equally ambitious effort to scale up other areas of decarbonization. Thus, positioning Canada as a global leader for low carbon products and industries.

In pursuing this opportunity, Canada will need to address important climate, environmental, practical, and public challenges in scaling up the carbon management sector. Projects will need to be evaluated on a full-lifecycle basis to ensure they are truly contributing to decarbonization, including documenting upstream and downstream emissions. Risks of leakage and risks of potential seismic events will need to be addressed. The need for land, significant volumes of fresh water, energy and other physical inputs must be properly understood and evaluated against alternative uses. All these factors can lead to understandable concerns by the public and, at times, even mistrust due to what some perceive as a lack of clarity about how carbon management activities are regulated. None of these challenges is insurmountable, but they will need to be tackled if the industry is to reach its potential.

A GROWING GLOBAL RACE

Many nations are actively pursuing the opportunities associated with carbon management. The U.S. is widely considered the global leader in this space, and the Biden Administration is picking up the pace. Of the 26 large-scale operating carbon capture and storage projects in the world today, half are in the U.S. Perhaps

more importantly, 12 of the 17 new carbon capture and storage projects announced in 2020 were US-based. And when Canada's Carbon Engineering announced it was building the world's first at-scale commercial direct air capture plant, it chose to locate it in Texas.

The growing investment south of the border is largely due to policy support. In particular, the U.S. government adopted the 45Q tax credit in 2018, which pays industrial manufacturers that capture carbon from their operations USD$50 per tonne of CO2 stored permanently, or USD$35 if the CO2 is put to use, such as for enhanced oil recovery (EOR). In addition to 45Q, the California Low Carbon Fuel Standard has helped boost investment in CCUS by offering up to approximately USD$200 credits for low-carbon fuels. And that is on top of hundreds of millions of financial supports, such as capital grants, from the U.S. Department of Energy.

The U.S. investment environment for carbon management will likely get a further boost this year from the Biden Administration's legislative agenda on climate. Bills circulating in the United States Congress include proposals to expand the 45Q tax credit to additional sectors, significantly increase the per-tonne credits earned, fund 10 carbon capture and storage demonstration projects (and 15 low-carbon hydrogen projects) and provide finance for the buildout of carbon transport and storage infrastructure. This underscores the need for several pathways to decarbonization in addressing the needs of different sectors and geographies.

The U.S. is hardly alone in its pursuit of carbon management. Both Norway and the U.K. have launched major carbon capture hubs around industrial sites that are linked to carbon trunk lines to sequester carbon in deep seabeds. The Northern Lights carbon capture and sequestration project in Norway is the world's first open-source CO2 transport and storage infrastructure that provides carbon storage under the North Sea as a service to large emitters. The private sector project partners are Equinor, Shell and Total, with considerable support from the Government of Norway, which views carbon captures as public infrastructure akin to roads and ports. In addition, the Netherlands has also just announced a major joint project with Royal Dutch Shell and ExxonMobil at the Port of Rotterdam, which includes up to USD$2.4 billion in funding from the government to capture 2.5 Mt of emissions.

CANADA'S OPPORTUNITY

Canada was an early pioneer in carbon capture and sequestration. The first large carbon capture project was launched in 2000 with carbon sequestered in the Weyburn-Midale (WM) oilfields in Saskatchewan, after being piped over 300 km north from a biogas facility in North Dakota. The WM project sequesters more than 1.8 million tonnes per year of CO2. It now can better be described as a carbon management system rather than a project, involving the capture, transportation, utilization and sequestering of carbon – all aspects of the value chain. Some of the CO2 now comes from a second project, the carbon capture unit that was added to the coal-fired Boundary Dam Power Station in southern Saskatchewan in 2014, the world's first post-combustion carbon capture plant. It has attracted international attention, drawing engineers from

around the world to study the process. It also led to the creation of the International CCS Knowledge Centre in Regina, a global centre of excellence with a mandate to advance the knowledge and application of carbon capture technology around the world.

Canada has since built two other significant carbon capture and storage projects, both partially funded by grants from the Government of Alberta and the federal government. The Quest project, operated by Shell but owned by the Athabasca Oil Sands Project (CNRL 70 percent, Chevron 20 percent, Shell 10 percent), sequesters approximately 1.2 Mt per year from hydrogen production at the Scotford Upgrader just northeast of Edmonton, transporting it via pipeline 65 km north for sequestration. Just south of Quest lies a fourth project known as the Alberta Carbon Trunk Line, which currently transports CO2 from two industrial facilities 240 km, where it is sequestered as part of Enhance Energy's enhanced oil recovery project. The pipeline is operated by Wolf Midstream, a unit of CPP Investments. Currently, it transports 1.6 Mt per year of CO2 but has capacity for just under 15 Mt annually.

These four large-scale Canadian projects represent a significant head start in the global race to prove carbon capture and storage technology and build carbon capture and storage infrastructure. Only the U.S. has more active projects. But, until recent weeks, Canada had no new major carbon capture and storage projects in its pipeline, in contrast to the dozens being developed south of the border and in Europe. Fortunately, that seems to be changing, with several new announcements this spring by companies moving ahead on CCUS to meet their environmental, social and corporate governance (ESG) and climate targets. In May 2021, the utility company ATCO and Suncor announced the first of several new CCUS projects near Fort Saskatchewan, Alberta, east of Edmonton. ATCO and Suncor plan to use CCUS to support the production of low carbon hydrogen (90 percent capture of CO2) for use at Suncor's neighbouring oil refinery, reducing refinery emissions by 60 percent. Additional low carbon hydrogen from the project would be available for blending into Alberta's natural gas supply, reducing emissions from natural gas end-use for those consumers.

In early June 2021, Air Products, the largest hydrogen producer in the world, announced plans to build a large-scale, low-carbon hydrogen plant in the Edmonton area. Scheduled to begin operations in 2024, the project envisions a CAD$1.3 billion investment in a hydrogen facility that could produce 500 kilotonnes of blue hydrogen, while sequestering more than 3 Mt of carbon annually in the process (at a 95 percent capture rate). This goes to the essence of the potential for Canada. Oil and gas are composed of both carbon and hydrogen molecules, thus forming hydrocarbons. The idea is to separate them, using the hydrogen for power, heat or as a feedstock and then either sequestering the carbon or finding non-emitting uses that will help pay for the process.

On the same day as the Air Products announcement, a group of five major oil sands producers representing more than 90 percent of production announced a joint commitment to net zero by 2050 that includes carbon capture facilities and a major carbon trunk line from the Fort McMurray area that can also pick up

emissions at other facilities, including forestry operations, along a route to its final destination. If realized – and the proponents have signaled that they are seeking major public investments to move forward – the multi-party project speaks to the potential growth of carbon capture in Canada. In fact, just a week after the oil sands net-zero announcement, TC Energy and Pembina pipelines announced plans to build the Alberta Carbon Grid, with up to 20 Mt of annual capacity, that could serve oil and gas as well as a range of other industrial emitters across Alberta.

Meanwhile, opportunity knocks in the cleantech sector. As the next frontier of point-source carbon capture and carbon dioxide removal develops, Canada has some promising companies poised to become world leaders. For example, B.C.-based Carbon Engineering is at the forefront in direct air capture, a technology that directly captures CO2 from the ambient air. Founded 11 years ago, Carbon Engineering is now developing the largest direct air capture plant in the world as part of a project with Occidental Petroleum in Texas.

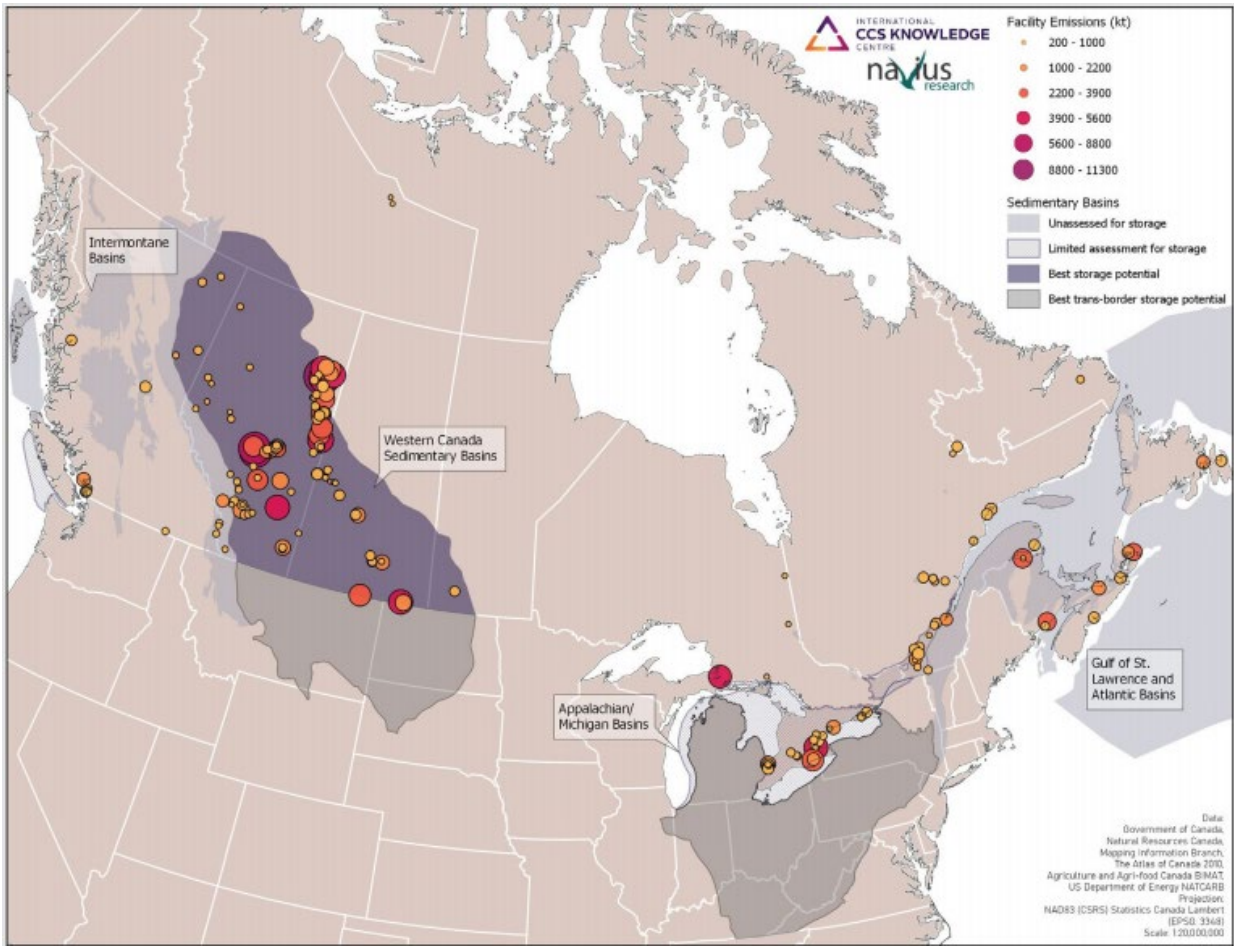
Another Canadian leader in carbon management is Svante, also based in B.C., which captures carbon directly from industrial point sources, such as at a Lafarge cement plant in Richmond, B.C. Svante was named to the prestigious Cleantech100 list in 2020, and recently closed the largest private investment into point-source capture ever (with funding that includes Suncor, Cenovus and Temasek).

In Halifax, Carbon Cure has developed a technology for the concrete industry that introduces recycled CO2 into fresh concrete to reduce its carbon footprint without compromising performance. It has just won the prestigious Carbon X-Prize, and also boasts investments from major financiers like Amazon and Breakthrough Energy Partners.

Beyond the promising companies we have in the race, there are many reasons to be optimistic that Canada can win in the carbon management market, including:

- **PORE SPACE:** As the shaded areas on the map below in Figure 4 indicate, Canada is blessed with abundant, well characterized geological formations, or pore space – well-suited for carbon sequestration. This is not true of all jurisdictions, including Western Europe and Canada where pore space is more limited.

Figure 4: Carbon sources and sinks in Canada



Source: The International CCS Knowledge Centre

- **EXPERTISE:** Our oil and gas sector and skilled workforce mean Canada has the right transferable skills to take advantage of this opportunity. And that's on top of all the innovative companies directly working on this problem today, including four Global Cleantech 100 companies, and three NRG-COSIA XPRIZE finalists.[4] Canada is also home to the International CCS Knowledge Centre, the Carbon Capture and Conversation Institute in Richmond B.C., the Alberta Carbon Conversion Technology Centre and CanmetENERGY research centres.
- **LAND:** We have vast land and natural open spaces – that other countries simply do not have – to develop many of the biogenic solutions.

[4] NRG-COSIA helps develop breakthrough technologies that convert CO2 emissions into useable products.

- **PERMITTING:** Unlike the U.S., the federal and provincial governments own the rights to underground pore space reservoirs, which enables stronger oversight and positions governments to more quickly enable projects.
- **MOTIVATION:** The imperative of national unity means we must find decarbonization solutions that recognize regional economic realities and differing opportunities, such as supporting Western Canada and the oil and gas sector; both the federal and provincial governments seem to be willing partners.
- **REGULATION:** Canada has well-developed regulations and skilled regulators, nationally and provincially, who understand how to oversee subsurface projects and are internationally recognized for their expertise and knowledge.
- **PUBLIC FAMILIARITY:** Canada's public, especially in Western Canada, has grown accustomed to large energy projects, including several carbon capture and storage projects.
- **SUITABLE ENERGY RESOURCES:** Canada's large deposits of natural gas mean that it can be a low-cost provider of hydrogen produced through steam methane reformation paired with carbon capture and storage. Similarly, Canada's abundant hydro resources make it well-suited to power carbon management projects with renewable energy.

CREATING A STRONG MARKET: THE CHALLENGE OF MAKING REVENUE EXCEED COSTS

Carbon management must be profitable to reach its full potential.

Unfortunately, the carbon management practices being undertaken today by much of the business community are seen as costs that have small or uncertain revenue streams. If Canada wants to attract the capital needed to invest in carbon management, it must find a way to demonstrate that these are attractive investment opportunities.

In this section, we review the costs and revenues associated with the sector and how to boost both certainty of revenues and returns of investing in carbon management. Given the rapidly evolving nature of the sector, it is likely that new business models and innovations will emerge in the coming years.

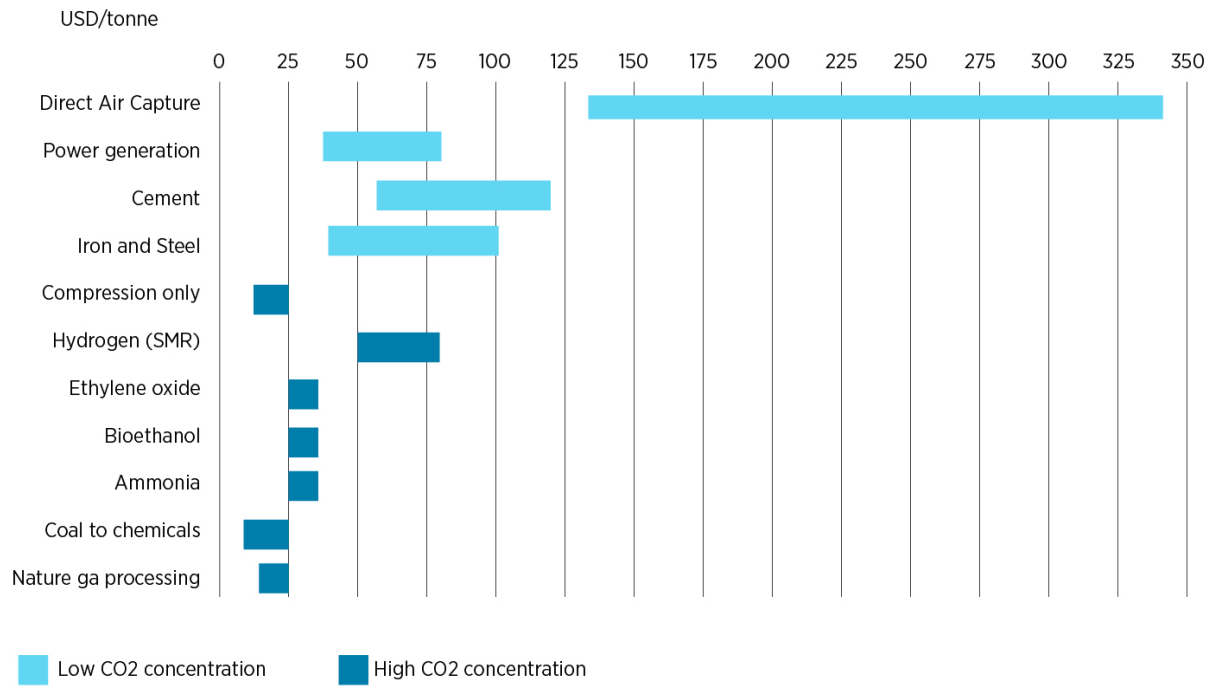
Costs

As a result of the heterogeneity within the carbon management space, costs vary widely across potential projects. Perhaps the biggest factor in driving cost differentials is the relative concentration of CO2 within the gas where it is being captured. Point-source capture from power generation facilities or industrial plants typically have gas streams with CO2 making up 10 to 20 percent or more of the total gas passing through the system, whereas direct air capture targets a CO2 stream that is just 0.04 percent of the volume of the ambient air cycling through the system.

But even industrial facilities vary widely with respect to capture costs because the gas streams have different partial pressures – a measurement of both concentration in the gas and partial pressure of the CO2 itself. Facilities engaged in natural gas processing, fertilizer or hydrogen production have some of the lowest costs because their partial CO2 pressures are 10 to 100 times higher than what may be found in facilities such as petroleum refining, power plants and cement kilns.

Of course, even within a sector such as hydrogen production, a set of project-specific factors dictate the ultimate costs of the carbon management project. Factors include the type of capture technology being used (there are many technologies and vendors), how much carbon is targeted for capture (it's rarely 100 percent, given the high cost, and can sometimes be as low as 60 percent), and what happens to the carbon after capture (further distances or non-pipeline shipping will raise costs).

Figure 5: Levelized cost of C02 capture by sector, USD (2019)



Source: International Energy Agency

Figure 5 is the International Energy Agency's summary of the cost of carbon capture across different industrial sources plus direct air capture. In general, costs of capture (before transport, utilization or sequestration) can be as low as CAD$30 to $40 per tonne for highly concentrated CO2 sources such as ammonia and more than $150 per tonne for cement.

In contrast, emerging technologies for carbon dioxide removal face higher costs. Direct air capture costs are currently between CAD$250 and $600 per tonne. And some emerging solutions are well over CAD$1000 per tonne.

But even the highest-cost technologies for carbon dioxide removal have a credible pathway to CAD$150 per tonne or lower in the coming decades (point-source carbon capture has an even better cost outlook). As with many other clean technologies, the key will be deploying technology to help bring down costs. Credible techno-assessments of direct air capture, for example, show that the costs could decline to USD$100 per tonne or lower by 2040. Heirloom, an enhanced weathering start-up, provides another good example of the expectations of cost declines. Heirloom has just sold its first tonnes of carbon removal for over USD$2,000 per tonne, but established investors have poured millions of dollars into the company on the belief that they can reduce costs to just USD$50 per tonne at scale. The company aims to remove a billion tonnes of carbon by 2035.

So how do we incentivize the deployment needed to bring costs down? The key is to ensure companies have revenue that investors can bank on.

Revenue

There are several options to avoid carbon costs and generate revenue for carbon management projects. In some cases, a project might benefit from more than one of the potential revenue streams described below. Without income streams, the proportion of costs borne by the consumer will have to be higher.

Utilization

One possible avenue to generate revenue is to sell carbon to entities that can use it in products that have monetary value. This type of CO2 utilization is already occurring on a relatively small scale, with carbon being used to stimulate growth in greenhouses, carbonate beverages, inject in cement and other uses.[5]

But the most significant market to date for CO2 has been enhanced oil recovery (EOR), where CO2 is injected underground to help extract oil from depleted oilfields. EOR is a core part of three-quarters of the active carbon capture and storage projects around the world, helping to provide a steady source of revenue. And while there is potential to expand EOR, it is unlikely that EOR holds the key to unlocking widespread carbon capture and storage. EOR on its own does not generate enough revenue to make higher-cost projects economically advantageous. There are only so many oilfields where EOR is suitable, and if oil demand begins to level off, this could further limit the potential of EOR.

[5] These uses have different implications for the length of time before carbon is released back into the atmosphere. Greenhouses only store the carbon for a very short period of time whereas injection into cement can keep the carbon locked away for thousands of years.

Whether to use EOR is a hotly contested topic. Many environmental groups have opposed EOR due to its role in producing more oil, a fact that may have contributed to the Government of Canada choosing to exclude EOR from its newly announced Investment Tax Credit. Yet, proponents of EOR emphasize that it has been critical to making carbon capture and storage projects viable. Without it, in their view, we would have fewer carbon capture and storage projects and more carbon in the atmosphere.

Over the long term, it is likely that for carbon management activities to gain widespread support, they will have to demonstrate that they can stand on their own without being chiefly used to produce more oil. But the absence of EOR revenue will certainly make the economics of many prospective projects more challenging and will place a higher onus on alternative sources of revenue and policy support. To date, 21 of the 26 large-scale carbon capture and storage facilities operating in the world have incorporated EOR into their projects.

Taken together, the overall market for CO2 utilization is quite small today, with global usage estimated at 230 Mt per year (Canada's pro-rata share would be about 5 Mt). There is certainly some potential to grow demand and, theoretically, a number of individual markets could employ well over a billion tonnes per year of CO2. But that reality is far from certain and would require CO2 to outcompete alternative inputs. It is entirely possible that utilization remains only a small part of the carbon management picture. The IEA, for example, envisions 90 percent of the carbon captured in its 2050 net-zero scenario being sequestered rather than utilized.

Nonetheless, important work is occurring today across Canada and around the world on ways we can use carbon to produce new high-value products such as carbon fibre or synthetic fuels. Some of this research is being conducted under the banner of Bitumen Beyond Combustion, sponsored by Alberta Innovates. While these efforts to find new uses for carbon hold promise, it is too soon to know whether any of the research being conducted will prove successful on a commercial scale. The carbon management industry thus cannot rely on these products to be the main catalyst of growth.

A notable and final option in the utilization category is hydrogen. There are high hopes for building out a hydrogen economy in Canada that can be a pillar of our decarbonization efforts. Hydrogen can be produced in several ways, including via electrolysis (green hydrogen if made from renewable electricity) or via steam methane reformation. In the latter case, the way to make hydrogen production a low-carbon process is to add carbon capture (creating blue hydrogen). If the low carbon hydrogen market sees significant growth, and blue hydrogen is seen as an attractive option, it could fuel strong demand for point-source carbon capture. Such market activity would have positive spillovers on the rest of the carbon management sector as the costs of capture technology decline, shared infrastructure such as pipelines get built and experience with carbon management work proliferates. As discussed earlier in the paper, ATCO and Air Products have just announced the first large-scale blue hydrogen projects in Canada.

Early Buyers

In the absence of a robust carbon utilization market, another promising option has emerged. A group of technology companies led by Stripe and Canadian-based Shopify have begun purchasing carbon dioxide removal even at very high price points per tonne. In fact, these companies have explicitly committed to be early adopters of high-priced carbon dioxide removal projects to establish the market and help carbon dioxide removal companies begin to move down the cost curve. They are willing to "overpay" for early credits as a service to the world, enabling costs to decline and thus opening the market to a wide array of future purchasers that are more price conscious.

These firms have made multimillion-dollar commitments to purchase carbon dioxide removal services from a diverse set of service providers that offer everything from tree planting to enhanced weathering to direct air capture. Shopify, for example, has committed to spending CAD$5 million annually. Its 2020 commitments include purchases from 11 different firms, including Canadian firms Carbon Engineering and Planetary Hydrogen. And other technology companies are also showing an interest in advancing the market for carbon dioxide removal. Microsoft purchased over a million tonnes of carbon removal in 2020 (mostly from nature-based suppliers) and has made a commitment to purchase 5 million tonnes annually by 2030.

The millions of dollars that these tech companies are deploying to help seed the market is a very positive start, but even at moderate per-tonne carbon costs, getting to scale will require hundreds of billions, if not trillions in capital.[6] That's among the reasons why policy will be so critical.

Public Policy

Government policy can and is helping to stimulate the market. Carbon pricing is one obvious way to create an economic incentive for both carbon capture and carbon removal. The expectations of a rising carbon price in Europe, for example, is fueling increased interest in carbon capture across that continent, with large projects already announced in Norway, the Netherlands and the U.K.

Until there is greater confidence in carbon pricing reaching a higher level, additional targeted policies will be needed. The U.S. has proven that production tax credits for carbon capture and storage can stimulate significant projects. Since Congress passed the 45Q tax credit in 2018, which offers a refundable USD$50 per tonne credit on sequestered carbon (and USD$35 for projects with income from enhanced oil recovery), more than 30 new carbon management projects have emerged. Canada announced a potentially similar investment tax credit in the 2021 budget – in this case, an investment tax credit that front-ends the support. Details on the policy will follow consultations.

[6] The National Academy of Sciences estimates that we'll need 10 billion tonnes per year of carbon dioxide removal alone. At $100 per tonne, a conservative estimate, that puts the market at $1 trillion.

Other policies that create a price on carbon or otherwise stimulate demand could also prove important. Canada's forthcoming Clean Fuel Standard (CFS) will allow companies to sell carbon credits to fuel distributors that need to comply with the standard. Based on the experience in B.C. and California, prices for those credits are expected to reach CAD$200 per tonne or more, though there is still some uncertainty, given that the CFS has been released only in draft form.

Further direct funding or procurement of carbon management could also help support growth in the industry. The federal and Alberta governments have both provided significant funding for previous carbon capture and storage projects such as the Alberta Carbon Trunk Line and the Shell-operated Quest carbon capture and storage project. Several other support programs have been announced by both levels of government, including Technology Innovation and Emissions Reduction grants, the Petrochemical Incentive Program in Alberta, and the federal government's CAD$8 billion Strategic Innovation Fund and CAD$1.5 billion Clean Fuels Fund, among others. The Canada Infrastructure Bank has also said that carbon management fits easily into its mandate.

The role of government policy to foster and support the public good inherent in reducing carbon emissions will be critical if Canada is to seize the climate and economic opportunity offered by carbon management. Other countries, for example the U.K., Norway and the Netherlands have committed major direct investments to offset the initial capital costs of project development.

As part of the work of the Energy Future Forum Carbon Management Working Group, we will develop a set of recommendations for how policy can effectively and efficiently spur growth in the carbon management space.

THE PLAYERS IN THE MARKET

If carbon management is to grow into a thriving industry, who will be the key players? A true industry implies multiple players interacting within an ecosystem – financiers, investors, upstream, downstream and specialists at various points along the value chain. In this section, we review some of the key suppliers and buyers of carbon management services. Our description below should not be considered comprehensive, but more illustrative of the types of actors that will enter the carbon management space. As we explain, there is also a notable difference between the point-source capture space versus the rest of the market.

Buyers – Point Capture

The demand for point capture is necessarily limited to facilities that have a point source of carbon that would benefit from capture technology. In Canada, Natural Resources Canada (NRCan) has estimated there are nearly 600 facilities that produce more than a 25,000 tonnes per year of CO2 that could benefit from CO2 capture. Of those facilities, 280 are oil and gas facilities, 73 are electricity generation facilities and 241 are in the heavy industry sector. These facilities produce a collective 264 Mt of CO2. If the average tonne

was captured for CAD$100 per tonne, that would place the market for these tonnes of CO2 at a theoretical CAD$26 billion per year.

Buyers – Carbon Dioxide Removal (Non-point source)

PRIVATE FIRMS

Twenty per cent of Fortune 2000 companies have net-zero pledges. In Canada, the momentum to net zero continues to build. Most recently, a group of oil and gas firms representing 90 percent of oil sands production announced a joint commitment to achieve net-zero emissions by 2050. Industry associations like the Canadian Steel Producers Association and the Mining Association of Canada have done the same.

Companies seeking to decarbonize have a variety of choices in addition to carbon management. Firms will choose to switch to renewable or low carbon energy, employ energy efficiency measures and create new processes or products that require less carbon in the first place.

But, inevitably, some emissions will require capture or offsetting negative emissions. On the capture front, there are some emissions, like those created in the process of making cement, that cannot be avoided and thus must be captured if we are going to avoid adding more carbon to the atmosphere. And there are other instances where capture will simply be a more affordable option for firms.

The biggest need for carbon management, however, will likely come from firms seeking to offset emissions for at least two reasons. First, emissions from some activities like long-haul aviation are currently very expensive to eliminate and thus will require an offsetting negative emission elsewhere in the economy. Plus, the net-zero pledges being made by firms include the entire supply chain associated with their products and services (Scope 3 emissions). Even if Apple, for example, can run its own operations with no carbon, it may still have to offset emissions within its supply chain if it cannot persuade its suppliers to zero out their emissions.

As mentioned earlier in the paper, a new and important dynamic in the private marketplace is that a series of technology companies led by Stripe, Shopify and Microsoft are making commitments to purchase carbon dioxide removal services. They are an important early buyer in these markets, though reaching scale may require hundreds more to follow in their footsteps.

GOVERNMENTS

In addition to implementing policies that stimulate the private market, governments will also play an important direct funding role to grow carbon markets. Public support will include funding for research, development and deployment; direct financial support for projects; and direct procurement of carbon dioxide removal to help governments offset their own emissions footprint. In Canada, for example, the

government recently committed CAD$319 million over seven years for research, development and demonstration projects to improve the commercial viability of CCUS. It previously provided CAD$120 million to the Shell Quest carbon capture and storage project to complement a CAD$745 million investment by the Government of Alberta. More recently, the federal and Alberta governments provided CAD$63 million and CAD$495 million, respectively, for the Alberta Carbon Trunk Line.

Many other governments are offering significant support for carbon capture and storage and carbon dioxide removal projects as well.

- U.S. President Joe Biden has proposed tens of billions of dollars of support for carbon capture and storage, including funding loan and tax grant programs for new industrial carbon capture and storage projects.
- The Norwegian government has pledged USD$1.6 billion for the Northern Lights project; and,
- The Dutch government recently announced a commitment of up to USD$2.4 billion in subsidies for a large carbon capture and storage project in the Port of Rotterdam.

Such pledges are likely to grow quickly in the coming decade as governments grapple with how to bring emissions in line with their ambitious 2030 and 2050 decarbonization commitments.

THE PUBLIC

The public at large may eventually become a source of demand for carbon dioxide removal activities. Already, Shell Canada has begun offering customers at its gas stations the opportunity to offset the emissions from their fuel use by paying an extra two cents per litre to support the conservation of B.C.'s Darkwood Forest, among other projects.[7] Shell has found 20 percent of its European customers have opted in to a similar program. Many airlines also offer offsetting emissions credits. Why wouldn't ride-hailing services like Lyft and Uber offer a similar service? In the longer run, technologies like blockchain may also allow users to directly purchase carbon offsets from suppliers of negative emissions on platforms.

SUPPLY

There are already a variety of purveyors of the technology needed to capture carbon from point sources and the ambient air. This includes established incumbents, as well as a growing list of startups, including some promising Canadian firms that are seeking to capitalize on what they expect to be a fast-growing market. As we explain below, existing oil and gas companies also have a potentially important role to play in delivering carbon management services (in addition to their role as developers of carbon capture).

[7] While this project employs nature-based carbon removal, the model could be used in the future for other non-nature based forms of carbon management as well.

CAPTURE – POINT SOURCES

A number of established global firms have offered capture technology for the 40 million tonnes of emissions being captured annually across the world. The precise technology used depends on the stage of capture (pre-combustion, post-combustion or oxy-combustion) and the method of capture (absorption versus adsorption). But there are several technology providers globally, including Mitsubishi, Siemens and Alstom.

Canada has at least one important player in this space. Svante technologies has developed an innovative capture solution that uses nanomaterials to produce a modular post-combustion carbon capture and storage system that the company says is half the cost of traditional carbon capture and storage. It has signed partnership agreements with large industrial players including Lehigh, Total and Husky and, more recently, received significant investments from both Suncor and Cenovus. Svante has also partnered with Swiss-based Climeworks to try to adapt its technology to the direct air capture market.

CAPTURE – AMBIENT AIR (I.E. NOT POINT SOURCES)

A variety of approaches exist to remove carbon dioxide from the ambient air. Direct air capture has received the most attention, but many other options exist and are being actively tested, as we describe below.

Within direct air capture, there are three key players: Climeworks, Global Thermostat and Canadian firm Carbon Engineering. All three have received significant support and made important strides building and operating capture projects around the world. Carbon Engineering, based in Squamish, B.C., was the first of the companies to build a large-scale commercial plant. Partnering with Occidental Petroleum, Carbon Engineering's technology will be used as part of a plant in Texas that will begin operating in 2024 and has the potential to capture 1 Mt per year.

As well, a range of new entrants into the air capture market aim to capture carbon using processes such as enhanced weathering and ocean-based removal. Many of these firms have emerged in just the last year, demonstrating the growing recognition of carbon dioxide removal's critical role in decarbonization.

Here are just a few examples of new entrants:

- Charm Industrial takes biomass, converts it into bio-oil and then injects it deep underground to create negative emissions. It has signed contracts with both Stripe and Shopify.
- Running Tide grows kelp that is sent out to the ocean on biodegradable buoys. Over time, after the seaweed has sucked in carbon, the buoys degrade and the kelp sinks to the ocean floor.
- Heirloom uses naturally occurring minerals that bind carbon to their surface, creating carbonates. The company aims to use this enhanced weathering process to capture carbon. Having formed in 2021, it already has a contract for carbon dioxide removal with Stripe.

- A Canadian company, Planetary Hydrogen, has an innovative process to produce hydrogen from electrolysis that also produces mineral hydroxide, a compound that can bind with carbon from the air and then be safely sent into the ocean to reduce acidity.

TRANSPORT

Carbon is not always captured in the same place where it will eventually be stored or utilized. That's why carbon pipelines will become increasingly important to safely and efficiently transport CO2 where it needs to go. In fact, investing in carbon pipelines could prove critical to developing the carbon management industry. For example, in the U.S., a recent Princeton study suggested the country will need 110,000 km of carbon pipelines to hit its net zero goal.

Canada's four large-scale carbon capture and storage projects – Quest, Boundary Dam, Weyburn-Midale and the Alberta Carbon Trunk Line – all rely on carbon pipelines. Regarding CO2 capacity, the largest is the Alberta Carbon Trunk line, which can carry nearly 15 Mt of carbon over 200 km. The trunk line is operated by Wolf Midstream, a Canadian firm that has a carbon business unit specifically devoted to carbon infrastructure.

In the near term, companies such as established pipeline players Enbridge, TC Energy and ATCO will begin offering carbon transport and sequestration as a service. Indeed, TC Energy and Pembina have recently announced their intention to build such a project: the Alberta Carbon Grid.

SEQUESTRATION

Sequestration is often completed as part of an integrated project owned by the same firm that does the capture, such as with the Quest project where the Shell-operated joint venture manages the entire value chain. But sequestration can also be provided by the pipeline as part of a sequestration service. And it may also be done by a separate company managing the sequestration specifically. For example, the Alberta Carbon Trunk Line delivers carbon to Enhance Energy, which sequesters the carbon as part of its enhanced oil recovery project.

The sequestration portion of the value chain is particularly important because it has historically been the case that government incentives to encourage both carbon capture and carbon dioxide removal have flowed to the agent doing the sequestration (rather than upstream to those providing capture or transport). Despite the large potential, there are relatively few operating commercial sequestration sites today, enabling the owners to charge high prices – sometimes as high as CAD$40 per tonne or more. Establishing sequestration sites and the associated transport infrastructure to ship carbon to those sites can make new carbon capture projects more attractive and can help foster carbon capture hubs. In a nod to the importance of sequestration, the Alberta Government has recently announced its intent to facilitate the sequestration

hub model that will provide sequestration as a service, while prioritizing the safety and permanency of storage.

UTILIZATION

There are a number of potential uses for CO2, though most current markets are fairly limited, as described above. There is no dominant player in the CO2 purchase market, but rather a wide variety of firms using the product for everything from injecting into cement to making plastics to carbonating beverages.[8]

Role of Oil and Gas Players

The role of existing oil and gas companies is worth highlighting specifically. These companies have the experience, expertise and equipment – and potentially the most incentive – to work across the entire carbon management value chain. They can serve both as buyers and suppliers of carbon management services and as marketers and traders of CO2 and CO2 credits. In some senses, capturing and sequestering carbon can be thought of as the same process as extracting oil and natural gas, but done in reverse. That means existing oil and gas players are well-suited to capture, transport, utilize and/or sequester carbon, marketing and trading it as needed.

The importance of oil and gas players is evident from a scan of global carbon management projects. Three European oil majors – Shell, Equinor and Total – are teaming up to offer carbon transport and sequestration services to industrial players across Europe as part of the Northern Lights project. Exxon has also been touting its ability to offer carbon management services across the globe. The company has just signed an agreement to manage one of the largest carbon capture projects in the world at the Port of Rotterdam and has proposed a 100 Mt carbon capture hub in Texas, among other projects.

Closer to home, several Canadian oil and gas players are investing in carbon management. Canadian Natural Resources Limited (CNRL) is involved in both the Quest project and the refinery that captures CO2 and sends it across the Alberta Carbon Trunk Line. Suncor has invested in capture firm Svante and recently announced its intention to build a 300,000 tonne per year hydrogen facility that will capture 90 percent of the CO2 and partner with ATCO to sequester it underground. Similarly, MEG energy has announced its intention to use carbon capture and storage to develop an oil field that sequesters enough carbon to offset its upstream emissions.

[8] Nonetheless, Canada does have some promising companies operating in this space, including Halifax-based CarbonCure which injects carbon into concrete and is on a mission to avoid 500 MT of carbon by 2030. It recently won the Carbon X-Prize.

THE BENEFITS OF CARBON MANAGEMENT

Economic Benefits

Carbon management has the potential to be a major new economic opportunity for Canada, given the expected growth in the global market. The International Energy Agency's 2050 net-zero scenario envisions 6.6 billion tonnes of point-source carbon capture globally by mid-century. It also envisions carbon dioxide removal of an additional 1 billion tonnes, though many other studies, including from the National Academy of Sciences, have suggested the carbon dioxide removal market may need to be 10 times that size by 2050 to avoid climate red lines.

Putting these estimates together, there is a clear pathway to a global market worth over USD$1 trillion. Canada's pro-rata share alone would be worth more than $20 billion per year, though there's every reason to think we could punch well above our weight given our many natural advantages. In fact, a recent study by the Canadian Institute for Climate Choices suggested that the path to net zero could include as much as 600 tonnes per year of carbon management (both carbon capture and removal) – worth well over CAD$50 billion per year.

A growing carbon management industry would translate into thousands of jobs, especially during the construction phase of the large infrastructure needed to kickstart this industry. As Figure 6 shows, carbon capture and storage projects create hundreds or even thousands of jobs during construction, depending on the facility. The buildout of pipelines will also create many new jobs. The 240 km Alberta Carbon Trunk Line, for example, created more than 1,000 jobs during construction and supported an additional 8,000 indirect jobs. As Figure 6 illustrates, the ongoing operational job figures are more modest.

Figure 6: Jobs from CCUS and direct air capture projects

			Project Jobs	Operation Jobs
CARBON CAPTURE RETROFIT (by facility type)	INDUSTRY	Steel mill	1,680-3,030	170-310
		Refinery	440-760	40-70
		Cement plan	430-690	60-110
		Hydrogen plant	175-300	20-30
		Ethanol plant	30-50	5-10
	POWER	Coal power plant	1,800-3,350	160-300
		Natural gas combined-cycle power plant	1,140-2,190	100-180
CO2 TRANSPORT INFRASTRUCTURE		Trunk line (20" diameter pipeline, 200 miles long)	1,250-2,190	8-20
		Feeder line (12" diameter pipeline, 50 miles long)	250-370	2-5

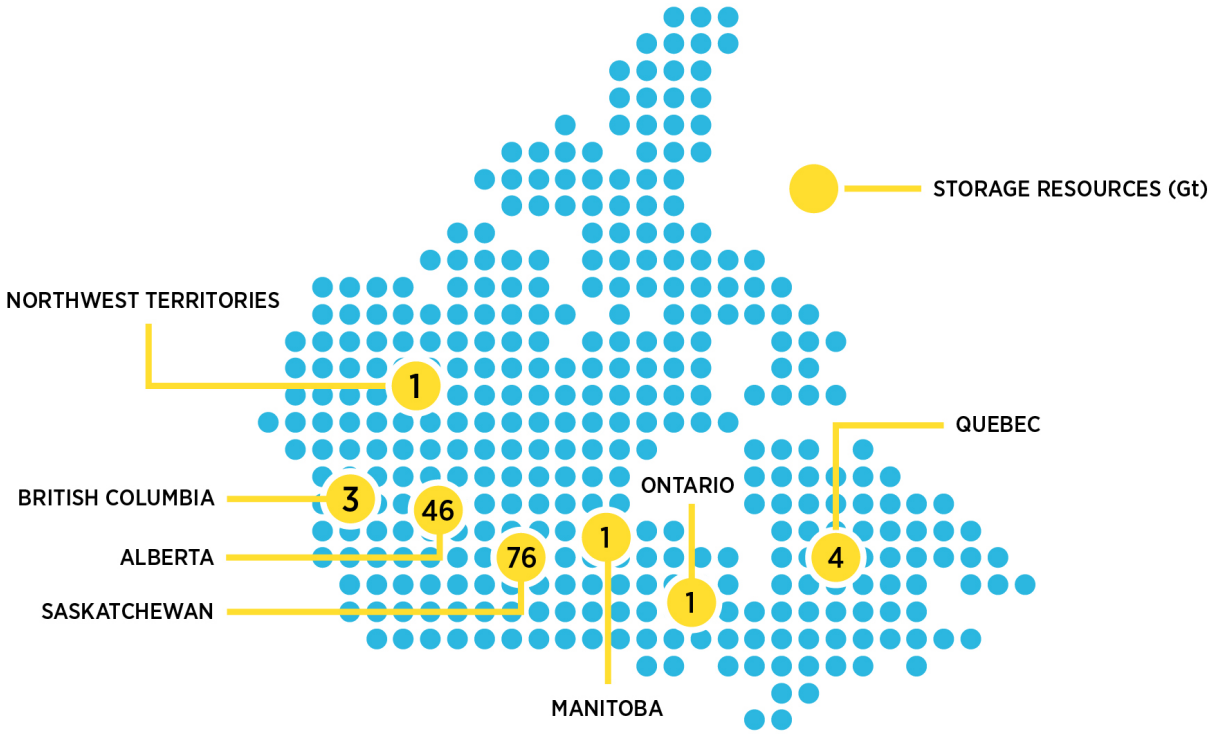
Source: Great plains institute.

The International CCS Knowledge Centre has estimated that just three large-scale carbon capture and storage projects would collectively provide more than 2,000 direct jobs and add more than CAD$2 billion in GDP annually for the four years of construction that would likely be needed to develop these projects.

There are other benefits too. Areas that have faced headwinds from the transition to a low-carbon economy stand to see significant benefit from activity in the carbon management space. For example, the vast majority of the pore space available to sequester carbon in Canada is located in Alberta and Saskatchewan, as shown in Figure 7 (though we may yet discover more deposits, including, as with the North Sea, offshore).

Figure 7: Subsurface sequestration of CO2 potential across Canada

Province/Territory	Storage Resources (Gt)
British Columbia	3
Alberta	46
Saskatchewan	76
Manitoba	1
Northwest Territories	1
Ontario	1
Quebec	4
Other Provinces/Territories	N/A
Canada *Canada has vast reservoirs that could be used for permanent CO2 storage	**132 Gt**



Source: National Energy Laboratory, Carbon Engineering

Note: The potential is likely even higher than shown, as not all subsurface space has been appropriately investigated.

Oil and gas expertise can also be leveraged for many of the economic opportunities within the carbon management space. For example, carbon will need to be transported in pipelines and will require subsurface drilling. Plus, some sequestered carbon will be injected into depleted oilfields (whether for EOR or not).

A significant share of the carbon management industry could flow to a sector and geographic region that has been challenged by the energy transition.

CONCLUSION

If the climate challenge confronting Canada is evident, so too is the economic opportunity out there to be captured. The twin objectives are clear and measurable: We must meet our 2030 GHG emission reduction targets on the way to a net-zero future by 2050, and we must do it in a manner that ensures jobs, growth and a strong economy. The good news is that a sightline to that future – one where a national carbon management strategy is critical to meeting our objectives – is coming into clear focus.

Whether it's the International Panel on Climate Change or the International Energy Agency, there is widespread agreement from these bodies that there can be no success in meeting global climate targets without the management of carbon through various forms of carbon capture. That fact is especially true for Canada. As other countries, such as the U.S., U.K., Norway and the Netherlands scale up investments in carbon capture and sequestration projects, Canada needs urgently to increase its commitment to a carbon management agenda. There is a growing global economic opportunity – in the form of engineered carbon management technology driven by the need to address climate change – that Canada must seize.

Fortunately, Canada has both the expertise and practical experience in carbon capture to be a world leader in the development and application of new technology. Canadian-based firms such as Carbon Engineering, Svante and Carbon Cure have attracted international attention for their innovative, leading-edge carbon management solutions. Canada, too, is home to four large-scale carbon capture, utilization and sequestration projects, including the Alberta Carbon Trunk Line, that are rapidly becoming the spine for a multi-economic sector carbon capture and sequestration system. And we are beginning to see the emergence of carbon-capture supported hydrogen projects that offer a clean energy future domestically and promise of a new export industry. The federal and Alberta governments have both signaled their intention to implement new policies that will give the carbon management sector a necessary boost. This is an encouraging start that now needs to become more systemic and strategic.

Clearly, when it comes to carbon management, need, opportunity and ability are aligned for Canada. Next comes a catalyst. What's required is to build a firm foundation by creating the right public policy and

regulatory environment. If that happens, investments will flow into a new sector that will create jobs, growth and opportunity while meeting our ambitious targets of reducing CO2 emissions.

This paper sets out the necessity of and opportunity for carbon management, how Canada can be a global leader and the issues and factors that must be considered and addressed. In the coming weeks, the Carbon Management Working Group will turn its attention to what specifically is required from governments and industry – whether in the form of policy frameworks or commitment to act – to lock in the conditions for success.

ACKNOWLEDGEMENTS

This paper is from the Energy Future Forum, a pan-Canadian group of organizations and individuals in business and government – along with academic, environmental and Indigenous organizations – working to address climate action and our energy future around one table. The Energy Future Forum is determined to see this collaborative effort map out an ambitious set of actions that are environmentally sound, economically beneficial and publicly acceptable.

The mission of the Energy Future Forum is "to develop practical measures that help Canada meet or exceed our 2030 emissions targets on the way to a net-zero future, and that strengthen an innovative economy, deepen shared prosperity and enhance national unity."

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