CIBC CAPITAL MARKETS

EQUITY RESEARCH

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CCUS: An Opportunity For Canada

Doin' It Right: Expectations For Federal Government Support On Carbon Capture And What It Means For Canadian Oil & Gas

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Sector:
Energy

Our Conclusion

Carbon capture, utilization and storage (CCUS) could transform Canadian oil and gas into one of the lowest GHG emission feedstocks in the world. We estimate the completion of the first tranche of proposed CCUS projects could reduce Canadian oil sands emission intensity by ~14%. Further, providing incentives for energy companies to build and maintain CCUS infrastructure could enable the decarbonization of up to ~75 MMtpa in proximal non-oil and gas industrial emissions, the equivalent of removing almost every ICE vehicle in Canada from the road. We view CCUS as being one of the largest near-term opportunities for Canada to advance its climate change agenda.

Key Points

What is needed from the government? At the current forecast price of carbon, we believe the government needs to provide at least 45% of total capex support to incentivize the construction of megatonne-scale carbon capture projects using existing technologies. Implementing new technology would likely need higher levels (up to 70%) of government involvement to help de-risk megatonne-scale projects. The opportunity cost for the federal government at ~50% involvement is ~$37/tonne, which is lower than the April 1, 2022, price on carbon of $50/tonne.

What is the risk of an unfavourable CCUS financial framework? Carbon emissions are a global issue and CCUS has entered a period of rapid growth. We believe the flow of funds will migrate to more favourable jurisdictions, and if Canada cannot create an attractive investment environment, it would squander the advantages it has over other global jurisdictions—such as expertise in reservoir management, experience in carbon capture, and geographic proximity of carbon emissions to storage. Without CCUS, we believe Canada will miss its climate change goals and reduce confidence in energy security for the country and its allies.

What could this mean for Canadian energy? Canadian oil and gas companies have traded at a discount compared to global peers given environmental concerns and despite strong social and governance performance. Global investors continue to focus on carbon intensity, but recent geopolitical events have underscored the importance of energy security. We believe a clear strategy to decarbonize through CCUS could remove one of the last barriers for investors looking at Canadian energy, and help close a valuation gap and drive outperformance vs. global peers.

Company-specific opportunities. We highlight the following companies with direct or indirect exposure to financial incentives from the government: AAV, EFX, POU, PSK and WCP. Further, we believe the oil sands companies (CNQ, CVE, IMO, MEG and SU) would benefit as well because a financial incentive structure would lower the capital-allocation risk associated with funding large-scale CCUS projects.

All figures in Canadian dollars unless otherwise stated.

For required regulatory disclosures please refer to "Important Disclosures" beginning on page 33.

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Executive Summary

In light of a shift in focus towards helping provide energy security for Canada's allies while balancing the need to decarbonize the economy, the Federal government has an opportunity to have its cake and eat it too. We believe a stable regulatory framework and financial incentives for CCUS could help industries representing at least 143 MMtpa in Western Canada lower carbon emissions. In this report, we have outlined several funding scenarios and financial frameworks that could encourage spending on major carbon capture projects to help Canada reach its climate change goals. The takeaways are as follows:

1) **Government needs to provide incentives to industry because carbon capture with current technology does not compete for capital.** Industry is actively pursuing technologies that can lower the emissions intensity of its barrels, but the pace of development and deployment relies on de-risking megatonne-scale carbon capture projects. We believe that a financial framework that incorporates at least 45% in government support in the form of an investment tax credit (ITC) would allow carbon-capture projects with existing (proven) technology to move forward at cost-of-capital breakeven economics. With relatively newer technologies, up to 70% support from the government would be needed to accelerate deployment of capital at breakeven economics. This suggests the government's opportunity cost on carbon capture is $35 to $92 per tonne, which is still competitive with other jurisdictions like the U.S. at ~US$50/tonne ($64/tonne).

2) **Participation in the growing carbon capture market has multiple benefits.** Canada is well positioned to participate in the estimated ~$1.2 trillion (Bloomberg New Energy Finance) of capital spending on carbon capture. Oil and gas companies have established a solid foundation to compete for global CCUS capital given their expertise in reservoir management over decades of resource development, the proximity of their operations to emission sources, and their experience in carbon-capture technologies currently used in existing operations and enhanced oil recovery. We estimate that just the first tranche of CCUS projects could reduce Canadian oil sands emissions intensity by ~14% to ~49.8 kgCO_2e/Bbl, which is comparable to the average global upstream carbon intensity of 55.0 kgCO_2e/Bbl. Subsequent phases could reduce emissions intensity to ~30.4 kgCO_2e/Bbl. We believe it makes sense for the government to leverage this advantage in expertise to achieve carbon-reduction goals and drive capital investment within the Canadian economy.

3) **Producer expertise could also help Canada achieve its emissions-reduction goals for other carbon-intensive heavy industries.** We believe there are synergies between oil and gas producers and other carbon-intensive industries that could help Canada reduce its overall emissions even faster. For example, Wolf Midstream, Enhance Energy and Whitecap Resources have signed agreements with various non-energy partners to capture and sequester carbon. Also, the carbon infrastructure proposed by the Oil Sands Pathways To Net Zero group is key to reducing ~75 MMtpa of heavy industry emissions concentrated in major industry hubs in western Canada. If CCUS technology is successfully deployed, it could help reduce emissions from industries representing over 40% of Canada's 2020 emissions. See Exhibit 11 on page 17 for an illustrative map.

4) **The lowest-hanging fruit for oil sands producers and Canadian refineries is sourcing blue hydrogen for upgrading and refining.** Oil sands companies are the largest producers and consumers of hydrogen within Canada. There is established technology that can substantially reduce the carbon intensity of hydrogen production by coupling it with CCUS. We believe there is a near-term opportunity to capture ~8.5 MMtpa of CO_2 at an initial capital cost of ~$17 billion, based on similar projects, before the end of this decade. Deploying capital towards this opportunity, however, depends on both a stable regulatory framework for carbon pricing and government

incentives because project economics currently do not compete for capital. Further development of blue hydrogen could advance the decarbonization of other industries in Canada and even provide low carbon energy for other parts of the world.

5) **Low-emission hydrocarbons would likely provide Canada with a strategic advantage moving forward.** While the energy transition is under way, we also believe it will span numerous decades. Within this time frame, we believe that low-carbon-intensity hydrocarbons will gain advantages in pricing and accessibility to funding. As CCUS reduces environmental concerns for investors, we believe this could narrow valuations of Canadian producers vs. global peers. Outside of oil sands companies, we see Canadian investment in CCUS as also being beneficial for natural gas supplies. Provinces like BC, Ontario and Quebec have low-emission power opportunities in hydroelectricity. Prairie provinces do not have the same advantage and likely need to rely on CCUS to moderate carbon emissions on their natural gas-fired power generation. We believe Entropy's pilot project at its Glacier facility provides a potential roadmap for further application across the province, and in other jurisdictions.

6) **Investing in this theme – AAV, EFX, POU, PSK, WCP**. AAV's subsidiary Entropy has developed a proprietary carbon-capture process and is the owner of a superior solvent technology that has lowered the levelized cost of carbon capture to be less than $50/tonne. EFX has contributed to the building of over 150 carbon-capture projects, and its process experience will likely make it a key competitor in the CCUS space, mostly focused on carbon capture. PSK carries fee title ownership across the Western Canadian Sedimentary Basin (WCSB), but most notably within Alberta near the industrial heartland, which is likely to be a key region in the future for CCUS hub applications. Also, PSK carries exposure to the Alberta Carbon Trunk Line, which is presently in operation, and its existing oil pools should continue to benefit from increased recovery of oil from CO_2 injection schemes. POU announced a potential project with a third-party provider to assess the opportunity for utilizing an oxy-combustion process that would result in ultra-low-emission power generation, CCUS and enhanced oil recovery (EOR) on its oil property. WCP has direct exposure through several MOUs and currently runs an EOR project in Saskatchewan that has sequestered ~38 million tonnes of CO_2 to date. Finally, on the midstream/pipeline side, we believe those companies will focus primarily on transportation and storage opportunities once a financial framework is provided by the government.

The Math…

We have built economic models based on two existing carbon capture projects. The table in Exhibit 1 below shows our assumptions for investing in carbon capture projects at a megatonne-scale. Our model is based on an existing blue hydrogen project (Quest) and an application of exhaust gas carbon capture (Boundary Dam). Each of these two projects was constructed at a 1 megatonne per annum (MMtpa) scale. The higher concentration of CO_2 in the blue hydrogen project lowers both capital and operating costs compared to the lower concentration of CO_2 and the presence of contaminants in the exhaust gas carbon capture application.

At a cost of capital of ~10%, we estimate at least ~45% of the initial capital spending needs to be supported by an ITC for economic breakeven. This implies an incentive of ~$35 per tonne is required for companies to move forward with a first round of CCUS projects. This level of government participation is significantly below prior investment levels in an existing megatonne-scale blue hydrogen CCUS project and the opportunity cost for the Canadian government is still lower than the U.S. 45Q regulation.

Assumptions

- Our estimates include ~$2 billion per MMtpa in costs associated with the carbon hubs, the connecting pipeline to the Cold Lake region, and the initial setup of the storage reservoir.
- We have used the Canadian government's price of carbon, which increases from $50 per tonne by $15 each year to $170 per tonne by 2030.
- Assets operate at a ~90% runtime.

Exhibit 1: CCUS – Assumptions Used In CCUS Economic Calculations, Current

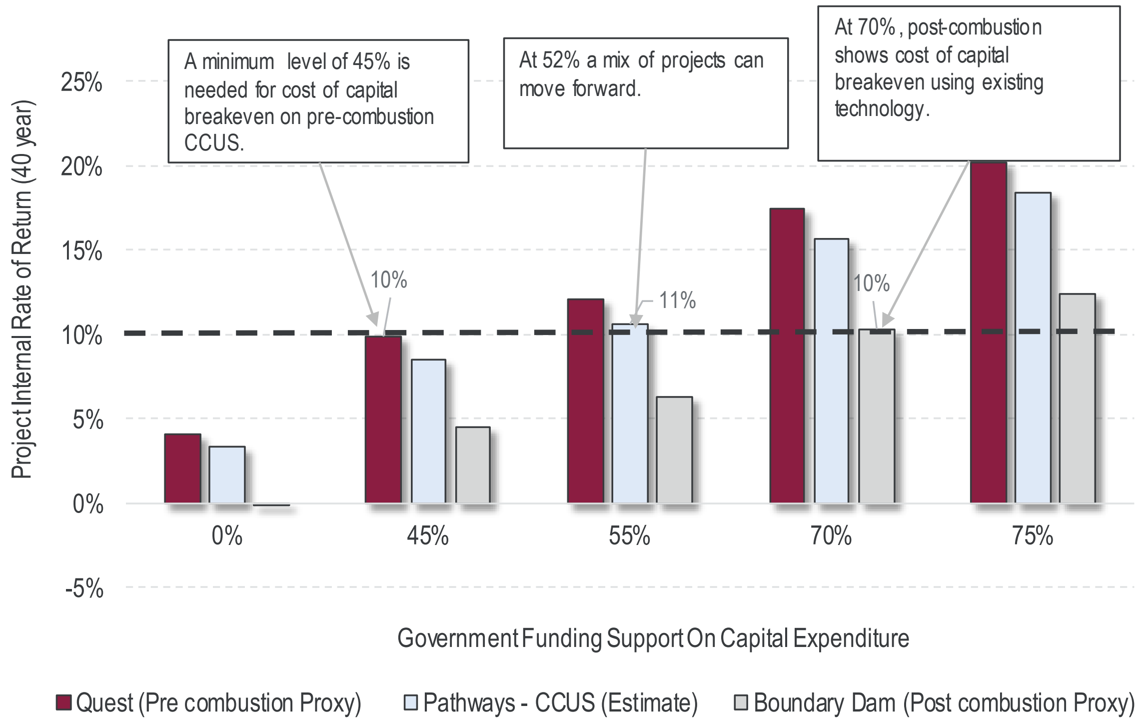
	Converting Grey Hydrogen to Blue Hydrogen	Exhaust Gas Capture
Proxy Project	Pre-combustion (Quest)	Post-combustion (Boundary Dam)
Initial Capital Spending	$1.8 billion initial capital spending cost per MMtpa.	$3.2 billion initial capital spending cost per MMtpa.
Operating Costs	$32 million per MMtpa	$40 million per MMtpa
Sustaining Capital	$5 million per MMtpa	$5 million per MMtpa
CO2 Concentration	~15-20%	~3% - 25%
Presence of Contaminants (Absorption Inhibitors)	No	Yes

Note: Initial capital spending is based on 3% inflation from original capital costs in 2015 for Quest and 2014 for Boundary Dam. There are no cost efficiencies incorporated into the initial capital spending, sustaining costs or opex vs. the sample projects.

Source: Company reports and CIBC World Markets Inc.

We have outlined several scenarios of government incentives on CCUS in Exhibit 2's bar chart. We believe an investment tax credit, redeemable in the year of spend at ~45% of the initial capital costs, could help accelerate projects like converting grey hydrogen to blue hydrogen, and an ITC of up to 70% could help accelerate larger-scale carbon capture from exhaust streams. At these levels, companies are able to cover their respective cost of capital while also advancing Canada's decarbonization agenda as long as the price on carbon does not change meaningfully.

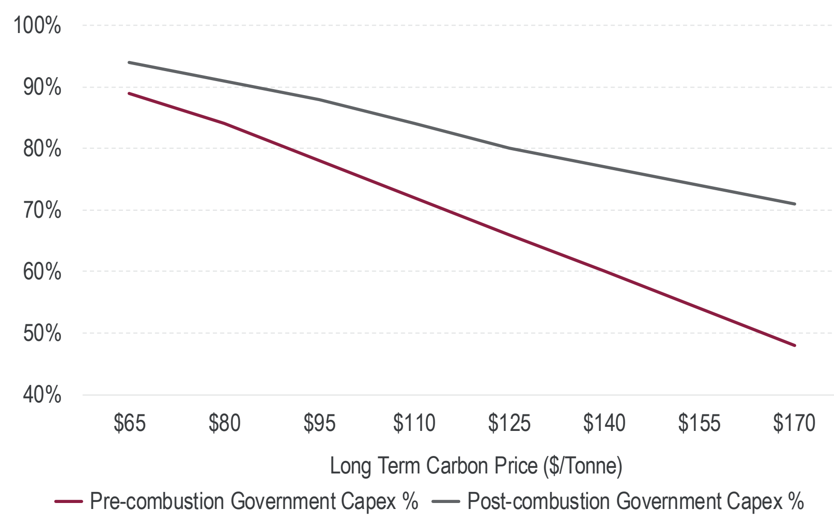
Exhibit 2: CCUS – Internal Rate Of Return At Various Levels Of Government Support, Current



Source: CIBC World Markets Inc.

Our economic model is based on the outlined federal price of carbon, which is set to increase from $50 to $170 per tonne in 2030. If the Federal government views the price of carbon to escalate to this point through time, subsidizing projects which help abate Canada's carbon emissions at an opportunity cost of $35 to $92 per tonne representing a fraction of the longer-term price to Canadians is a prudent investment. Given the carbon price is set by the government, we believe companies would be hesitant to invest billions of dollars on CCUS projects without a combination of regulatory and pricing certainty. In the line chart in Exhibit 3, we highlight the capex contributions we estimate are needed from government to allow companies to achieve an IRR of 10% at various long-term carbon prices.

Exhibit 3: Energy – CCUS Government Capex Contribution At Various Carbon Prices, Current



Source: CIBC World Markets Inc.

Alternative Funding Models

If the government decides against direct involvement via a tax credit, we view the financing of carbon capture projects as being more of a cost-of-capital and risk-mitigation issue. Further, we believe companies are concerned about allocating capital towards projects where there is little certainty, predictability and potentially consistency from government-imposed forward pricing. We have highlighted several alternative funding scenarios that could help moderate the cost burden or lower the economic threshold of sanctioning CCUS projects, although they would likely still delay the timing of capital deployment.

Companies are being asked to commit cash flow towards projects that generate meagre returns below the WACC of the industry, or deploy early-stage technology with no history of scalability. This necessitates help from the government.

1) **Preferential loans:** If the government decides against directly participating or providing some kind of tax incentive, we believe the accessibility of low-cost debt could help finance a carbon-capture project. However, this scenario would require at least 25% of debt at a bond yield of 2.3% (after-tax) to reduce project opportunity cost to ~10%. Currently, we have only seen basis-point-level improvements on interest rates for sustainability-linked bonds.

2) **Third-party construction of the facilities:** If third parties (typically those that can accept a lower internal rate of return) partner with companies that have expertise, we believe CCUS projects could move forward. We highlight the recently announced agreement between Wolf Midstream, Whitecap Resources, First Nation Capital Investment Partnership and Heart Lake First Nation as a group that could help tackle the problem of lowering GHG emissions in the Alberta Heartland Region. We estimate a cost of capital of the third party would have to be ~4% or lower to drive a cost-of-capital return on CCUS projects at the megatonne-scale.

3) **Enhanced oil recovery:** The use of CO_2 for enhanced oil recovery is a proven concept with decades of demonstrated success. We view the sale of CO_2 to producers that use the gas to improve productivity of a reservoir as helping offset the significant cost of capture emissions. In the U.S., anthropogenic or even produced CO_2 can be sold at ~US$20-$30/tonne to oil producers, who will then also pay for transportation and eventual injection into reservoirs. Producers in the U.S. see the net benefit in lowering decline rates and increasing recoveries from conventional reservoirs. The use of CO_2 in a tertiary (enhanced) oil recovery scheme can have ancillary benefits for Canada's decarbonization plans in that existing expertise and knowledge of reservoirs could accelerate the decarbonization of other industries (namely those in Alberta's Industrial Heartland).

The Prize…

Canada's current 2030 emissions target is an estimated range between 406 to 443 MMtpa. This target, revised in July 2021 in tandem with Canada's updated Nationally Determined Contribution submission to the United Nations, represents aggregate emissions declines of about 40% to 45% from 2005 levels. Since 2015, the Liberal government announced just over $150 billion of investments to help the transition to a more carbon-efficient economy. However, only 6% of funding is earmarked to oil and gas even though it is the largest emitting sector at 27% of emissions. The bulk of funding (over 60%) is currently allocated to transportation, electricity, and waste/other (40% of emissions). We believe a financial framework that incentivizes industry to build out the initial infrastructure to grow Canada's carbon capture, utilization and storage (CCUS) industry could help achieve the country's emissions-reduction targets and drive significant economic benefit at the same time. The table in Exhibit 4 highlights historical and forecast Canadian emissions and government funding by sector.

Exhibit 4: Canadian Emissions – Total Emissions And Federal Funding By Sector, 2020 and 2030E

Emissions (MT) by	Canadian Emissions		2030 vs 2020		Federal Funding	
Economic Sector	2020	2030	MT	%	$ bln	%
Oil and Gas	179	110	-69	32%	9.5	6%
Transportation	162	143	-19	9%	62.9	42%
Buildings	85	53	-32	15%	18.1	12%
Heavy Industry	69	52	-17	8%	5.8	4%
Agriculture	72	71	-1	0%	1.2	1%
Electricity	52	14	-38	18%	19.6	13%
Waste & Other	50	29	-21	10%	25.6	17%
LULUCF	-10	-30	-20	9%	8.7	6%
Total	**659**	**443**	**-217**	**100%**	**151.3**	**100%**

Note: Numbers may not sum to the total due to rounding. Current 2030 emissions by sector (i.e., 420 MT) estimated by CIBC. Federal funding values as of November 2021.

LULUCF = Land use, land-use change, and forestry.

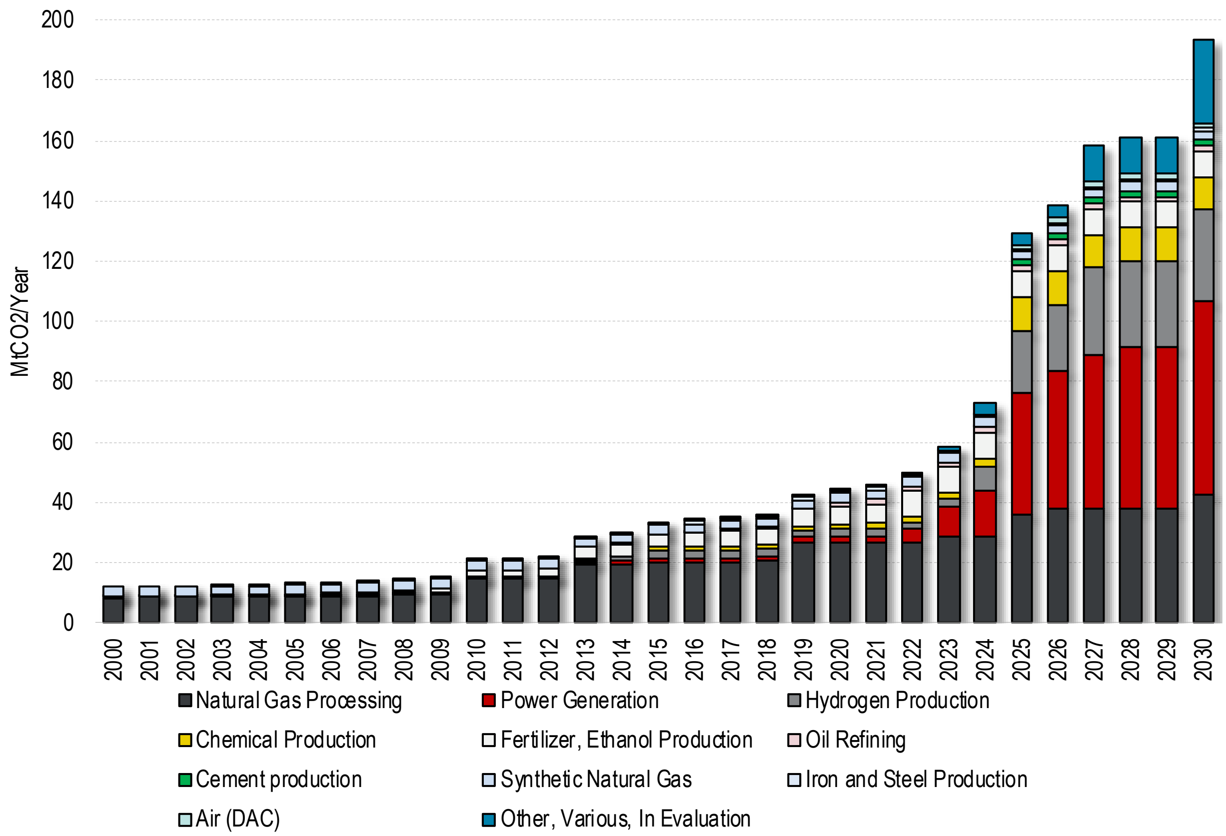
Source: Environment Canada and CIBC World Markets Inc.

Significant Total Addressable Market (TAM): The World Is Your Oyster

The market for reducing carbon emissions already exists in scale, and CCUS is a key way the world can lower absolute emissions. It is applicable to several industries such as natural gas processing, concrete and building materials, petrochemicals, power generation, fertilizers, and oil refining. As capital chases a solution to reduce carbon emissions across these industries, it will still migrate to more favourable jurisdictions, which would provide a significant incentive to create an attractive environment for capital allocators to invest within Canadian borders.

The capacity of announced projects grew from 75 MMtpa at the end of 2020 to 111 MMtpa in September 2021, implying a ~48% increase. BNEF (Bloomberg New Energy Finance) data suggests the CCUS market could grow at a CAGR of ~16% by the end of this decade. Currently, there are 28 operational facilities around the globe with current capture capacity of ~40 MMtpa vs. potential capture capacity of over ~5,600 MMtpa in 2050 (or 140x the current size). The stacked column chart in Exhibit 5 highlights global CO_2 capture capacity growth as forecast by BNEF.

Exhibit 5: CCUS – Global Capture Capacity Including Utilization And Storage, 2000 - 2030E



Source: BNEF and CIBC World Markets Inc.

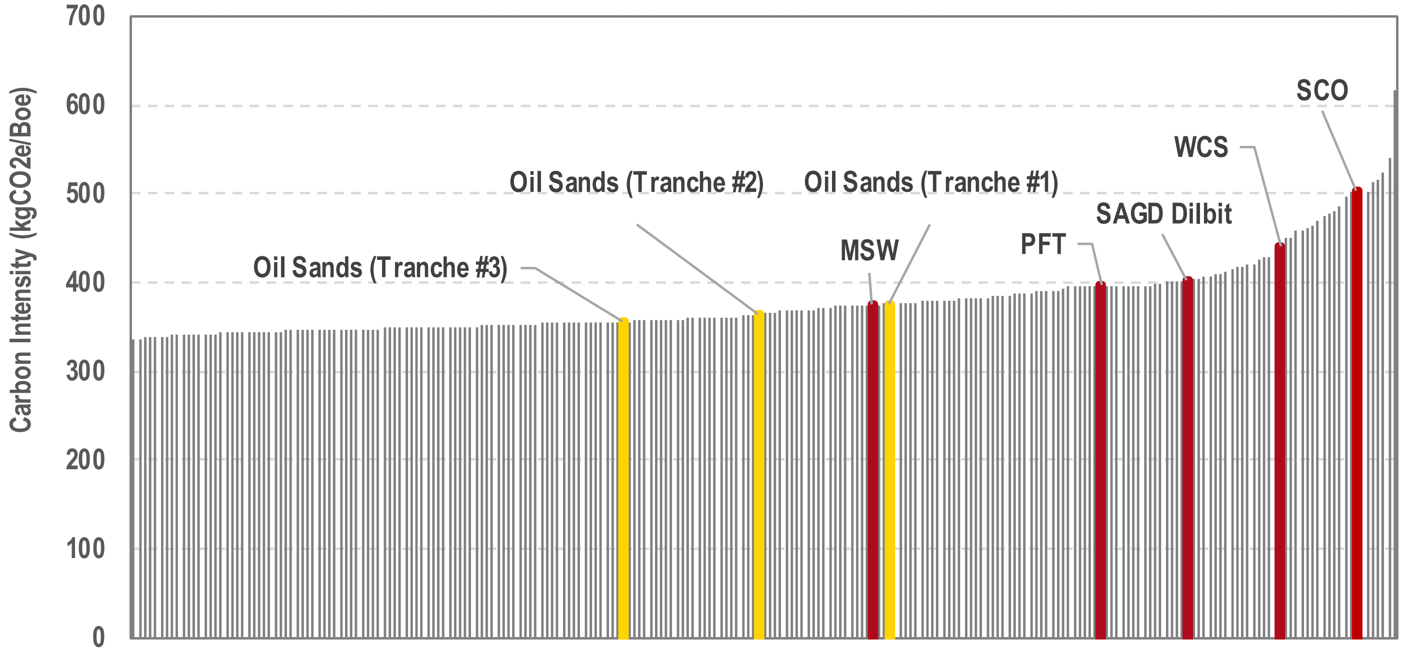
Capital spending to capture ~5,600 MMtpa could exceed $1.2 trillion according to BNEF data. We believe that a financial framework that incentivizes carbon-intensive industries to collaboratively work towards a lower-carbon future could have significant incremental economic benefit for Canada beyond direct and indirect GDP contribution from oil and gas. We admit that CO_2 storage is the primary result of current capture projects. As CO_2 demand increases beyond its use in enhanced oil recovery, the incremental growth could help Canada's "Just Transition" for those individuals/workforces potentially affected by the evolving energy needs of the world.

Competitive Emissions Intensity Vs. Global Benchmarks

CCUS could help reduce oil sands emissions intensity by over 50% when combined with other technologies and efficiencies, making it an environmentally attractive feedstock.

With the help of carbon capture, the Pathways Initiative could transform the oil sands into one of the lowest GHG emission feedstocks in the world. We estimate the successful completion of proposed CCUS projects (the first tranche) could reduce Canadian oil sands emissions intensity from ~57.0 to ~30.4 kgCO2e/Bbl. With the second tranche of carbon capture, synthetic crude oil could become one of the lowest carbon intensity barrels in the world. The column chart in Exhibit 6 compares global carbon intensity to the carbon intensity of assets across the WCSB.

Exhibit 6: Carbon Intensity – Comparative Global GHG Intensity (Wells To Wheels), Current



Note: Assumptions of 26 kgCO2e/Bbl associated with refining and 300 kgCO2e/Bbl associated with combustion.

MSW = Mixed Sweet Blend, PFT = Parafinnic Froth Treatment, SAGD = Steam Assisted Gravity Drainage, WCS = Western Canadian Select, SCO = Synthetic Crude Oil

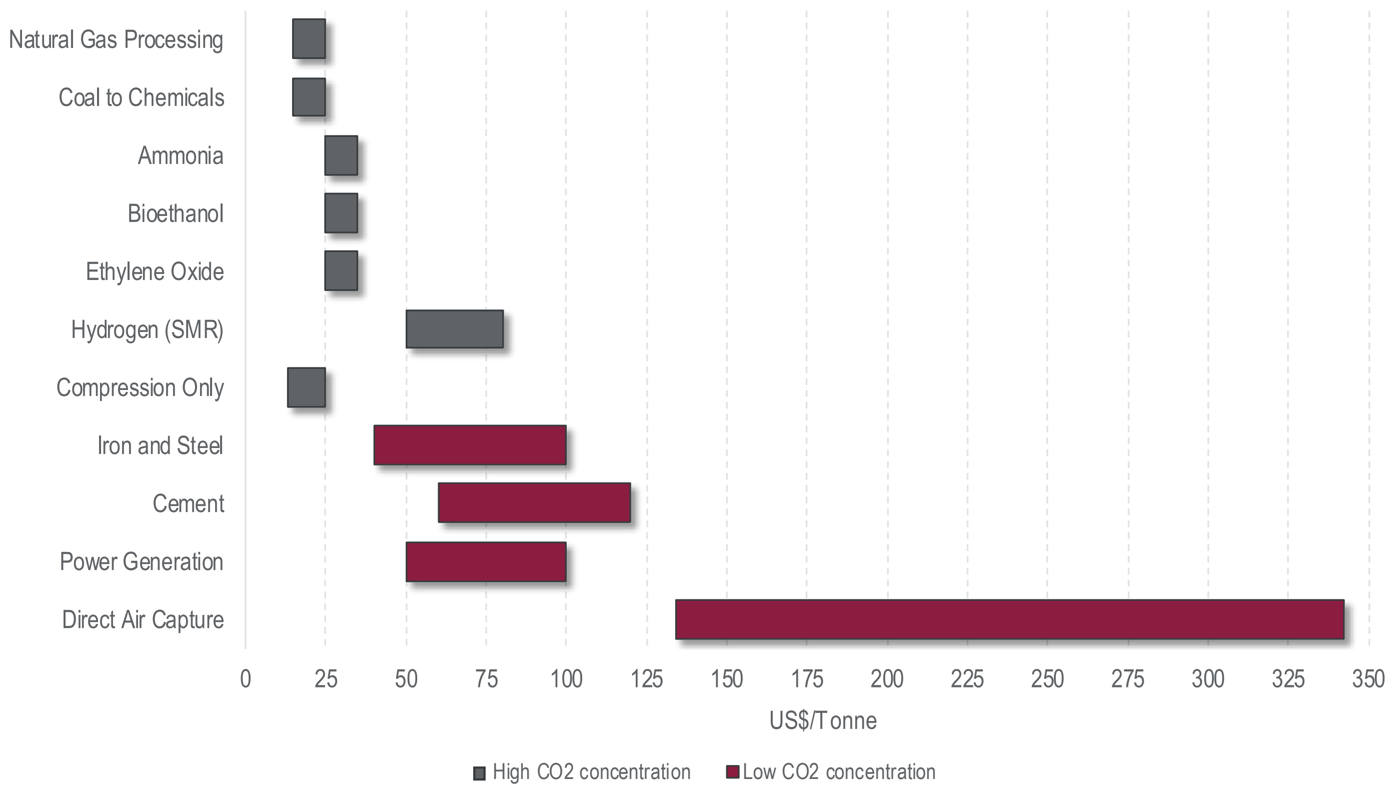
Source: California Air Resources Board and CIBC World Markets Inc.

The First Step Doesn't Have To Be The Hardest…

We believe the oil sands companies will likely start with the lowest hanging fruit in converting grey hydrogen into blue hydrogen for upgrading heavy crude. The process captures CO_2 from syngas in the process of making hydrogen and can help remove ~8.5 MMtpa from the first phase at a capital cost of ~$2 billion per MMtpa. We suspect that this could allow companies to set up the initial infrastructure and lower the burden on future projects.

While many technologies designed to capture and remove carbon from product streams have been used through time, there is a wide range of costs associated with them, especially when dealing with lower concentrations of CO_2. There are other considerations, such as contaminants that could inhibit the capture of carbon, operating conditions, and energy requirements as other primary determining factors could influence the cost of a project. The bar chart in Exhibit 7 shows the levelized range of costs per tonne of CO_2 by source. In general, the cost of CO_2 capture is lower for higher-concentration sources than for lower-concentration applications.

Exhibit 7: CO_2 Capture – Levelized Cost By Sector And Initial Concentration, 2019



Source: IEA and CIBC World Markets Inc.

Canada's Strengths And Advantages

We believe Canada has an advantage in CCUS compared to other jurisdictions given the geographic concentration of the oil sands, a good understanding of geology, and extensive experience and knowledge of carbon capture, transportation and storage at various scales.

Geographic Concentration Of The Oil Sands

Given the concentration of emissions from industrial complexes or oil and gas extraction, the construction of carbon-gathering hubs and trunklines to move carbon emissions from a point source could substantially lower the cost of implementing CCUS and achieving Canada's emissions target.

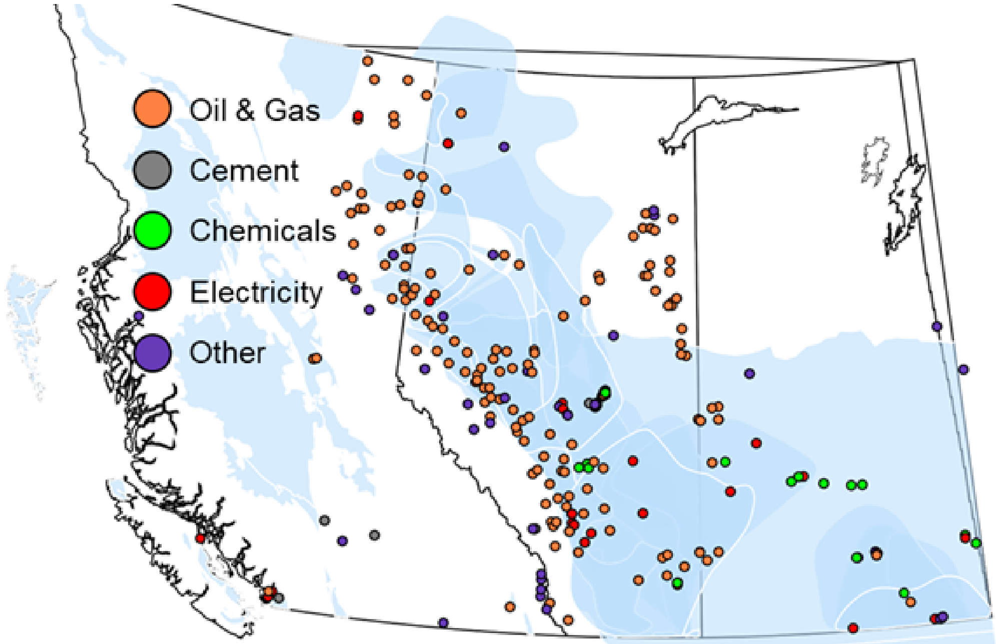
The geographic concentration of the oil sands offers an advantage when implementing carbon capture compared to U.S. shale. There are several potential CCUS projects in hydrogen within the Fort McMurray area, which could be a first leg in reducing absolute emissions. Beyond these initial projects and targeting post-combustion applications within the oil sands, CO_2 emissions can be narrowed down to less than 300 major emissions sources from boilers, co-gens, HRSGs and OTSGs across the five oil sands mines and 13 in situ facilities that make up the Pathways Initiative companies. While the design and selection of technology still pose an incremental level of complexity, CCUS deployment in the oil sands is significantly easier than applying this technology at tens of thousands of conventional wells and flare stacks or thousands of gas-processing facilities across North America's conventional basins. Further, capital costs can be amortized over decades given the reserve life of the oil sands, moderating the impact on unit supply costs.

Good Understanding Of Geology

The oil and gas industry has years of experience injecting CO_2 into geological formations and millions of tonnes of CO_2 are already injected annually in Canada. Depleted hydrocarbon reservoirs are ideal storage vessels for CO_2 and are abundant in the WCSB. Further, given the experience within the basin, companies likely already have a good understanding as to where there could be viable large storage reservoirs that could accommodate sequestration. We estimate the cost of storage could be ~US$5 to $10 per tonne depending on the regulatory environment for monitoring and liability management costs.

For underground storage, there are three major targets for CCUS within Western Canada: hydrocarbon (oil & gas) reservoirs, un-mineable coal, and saline aquifers. Injection of carbon into oil and gas reservoirs makes up the bulk of existing CO_2 storage, even if that pore space only makes up ~7% of available reservoir capacity in North America. Saline aquifers, which make up ~91% of the total estimated potential carbon storage capacity in North America, would be a key next step in accelerating CCUS development. Given the nature of oil and gas development across the Western Canadian Sedimentary Basin, we believe industry has a large enough dataset to identify and begin evaluating these reservoirs for potential CO_2 storage. Further, as shown in the map in Exhibit 8, the distribution of saline aquifers exhibits a significant overlap with stationary CO_2 sources across Western Canada.

Exhibit 8: Energy – Location Of Saline Aquifers And CO_2 Sources In Western Canada, Current



Source: geoSCOUT and CIBC World Markets Inc.

Canada Already Has Experience In Carbon Capture

The most common application of carbon capture is in acid gas removal from natural gas processing. This traditionally uses a liquid adsorption technique within a tower and has been employed for decades to “sweeten” natural gas at scales well below the megatonne level. There are two projects within Canada that have achieved the megatonne scale: Shell’s pre-combustion project Quest and SaskPower’s post-combustion project at Boundary Dam. Meanwhile, Entropy is developing a proprietary design and solvent for low-capital, modular CCUS, and Svante is developing proprietary solid sorbent materials and nano-filters to efficiently capture CO_2. The Appendix beginning on page 21 of this report outlines the technologies that are being applied and developed within Western Canada and North America.

Building Out The Initial Infrastructure Lowers Costs Of New Technology Deployment

If new technology development is burdened with capital spending on greenfield infrastructure, economic thresholds will be even harder to reach. Many of the technologies extracting low concentrations of CO_2 at megatonne-scale from exhaust streams still need work to drive down costs. Capturing CO_2 from exhaust streams is costly, especially when dealing with lower concentrations. Exhaust from Once Through Steam Generators (OTSGs) can range from ~9% to 10% CO_2 concentration and exhaust from efficient cogeneration units can be as low as ~4%. The scale-up of this technology is challenging (or more expensive) because the traditional solvent technology becomes less efficient in higher concentrations of oxygen, lower CO_2 concentrations and lower pressure exhaust streams. We believe that it could take time (years or decades) for various technologies and techniques to be tested at increasing scales before companies feel comfortable risking capital to develop multi-billion-dollar capture projects without substantial government support.

Why Government Should Provide Financial Incentives

We believe the government will need to play a key role in moving CCUS projects forward. Specifically, we believe government will need to provide a clear regulatory environment that includes financial incentives, for several reasons.

1) Changing regulatory environments have caused monumental shifts in the assumptions companies use to form the basis of their project economics. We highlighted these concerns in our report **Government's Role In The Energy Transition**.

2) Deployment of the newest technology at scales necessary to accelerate decarbonization is still relatively unproven, and projects with proven technology do not meet existing economic thresholds.

3) Global concerns about climate change are being balanced with the need for energy security (given recent geopolitical events) and moderating the impact of inflation.

4) Historically, companies have mitigated pricing volatility in commodities through partnerships with other companies to distribute risk. This cannot be done when there are conflicting opinions across party lines on the primary characteristics of carbon pricing.

For these reasons, we view it as imperative that any government legislation that incorporates incentives for industry to pursue carbon-capture projects receive bi-partisan support in Canada. We highlight recent reversals of major approvals in the Energy East, Northern Gateway and Keystone XL projects, which drove significant losses for the industry. These decisions are fresh in the mind of oil and gas companies, as they seek assurances on the permitting landscape ahead of key capital allocation decisions.

Net benefits from helping move CCUS forward

CCUS facilities create and sustain high-value jobs, while building support for strong climate action. These facilities begin as large engineering and construction projects that take years to plan, design, construct and commission. At its peak, the Boundary Dam CCS facility in Saskatchewan employed a construction workforce of 1,700, while the Alberta Carbon Trunk Line employs up to 2,000 people. The table in Exhibit 9 below shows the net present value of government investment at various levels based on an IRR of 2.45%, which is our forecast 30-year government bond at the end of 2023. In the calculation, we factor in the tax benefits that both Federal and provincial governments would receive from both individuals and companies that provide services to the projects. We highlight that even with a 50% capital contribution, the government would still be able to make a positive NPV from the investment. In the table below, we also highlight a few different scenarios of government contribution to CCUS projects while still achieving positive NPV on tax benefits for an operating project alone.

Exhibit 9: CCUS – Government's Investment NPV ($MM) At Various Funding Levels, 2023E - 2053E

Government contribution on OPEX (columns); Government contribution on CAPEX (rows)

	0%	10%	20%	30%	40%	50%	60%	70%
0%	6,746	6,225	5,703	5,182	4,661	4,139	3,618	3,096
5%	6,117	5,595	5,074	4,552	4,031	3,509	2,988	2,466
10%	5,487	4,966	4,444	3,923	3,401	2,880	2,358	1,837
15%	4,857	4,336	3,814	3,293	2,771	2,250	1,729	1,207
20%	4,228	3,706	3,185	2,663	2,142	1,620	1,099	◆ ▲ 577
25%	3,598	3,077	2,555	2,034	1,512	991	◆ ▲ 469	(52)
30%	2,968	2,447	1,925	1,404	882	◆ ▲ 361	(160)	(682)
35%	2,339	1,817	1,296	774	◆ ▲ 253	(269)	(790)	(1,312)
40%	1,709	1,188	666	◆ ▲ 145	(377)	(898)	(1,420)	(1,941)
45%	1,079	▲ 558	◆ ▲ 36	(485)	(1,007)	(1,528)	(2,049)	(2,571)
50%	▲ 450	◆ (72)	(593)	(1,115)	(1,636)	(2,158)	(2,679)	(3,201)
55%	◆ (180)	(702)	(1,223)	(1,744)	(2,266)	(2,787)	(3,309)	(3,830)
60%	(810)	(1,331)	(1,853)	(2,374)	(2,896)	(3,417)	(3,939)	(4,460)
70%	(2,069)	(2,591)	(3,112)	(3,633)	(4,155)	(4,676)	(5,198)	(5,719)
75%	(2,699)	(3,220)	(3,742)	(4,263)	(4,785)	(5,306)	(5,828)	(6,349)

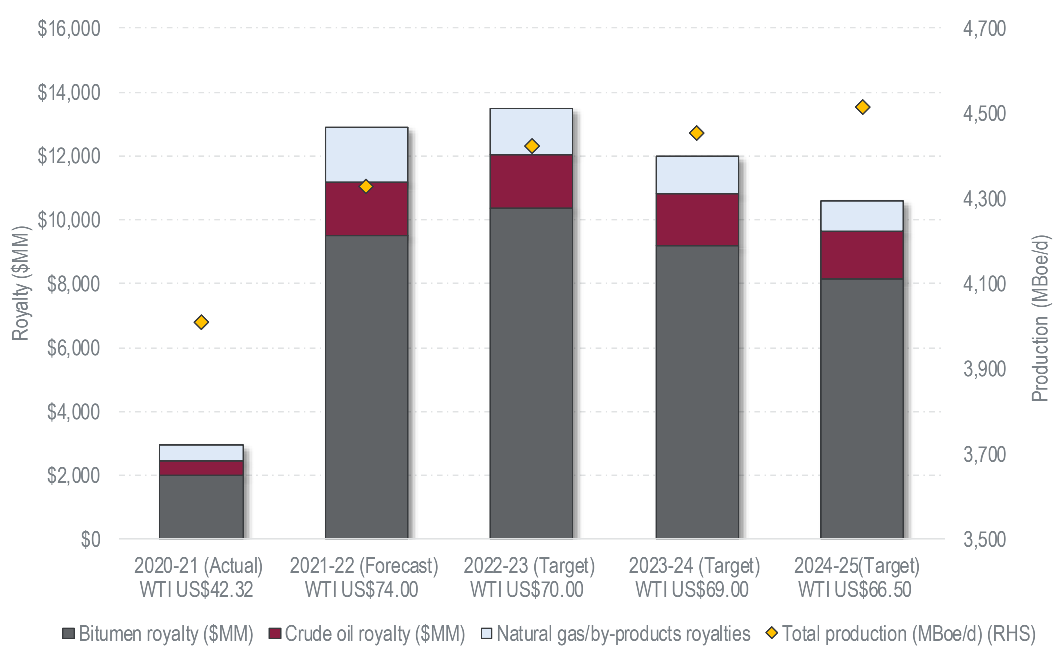
◆ Companies could see IRR of 10%, ▲ Government could achieve breakeven

Note: Based on $17 billion initial capital cost.

Source: Company reports and CIBC World Markets Inc.

Further, we also estimate provincial governments could benefit from increased longevity of production (and royalties), which would drive significant further benefit locally. As other industries such as blue hydrogen continue to grow, feedstocks like natural gas could see incremental local demand. The stacked column chart in Exhibit 10 highlights Alberta's royalty income from the province's 2022 budget.

Exhibit 10: Government Of Alberta Budget 2022 – Royalty Revenue, 2021 - 2025E



Source: Alberta Government and CIBC World Markets Inc.

Sharing Is Caring: Lower CCUS Costs For Other Industries

We view the experience of Alberta's energy companies in managing reservoirs to be helpful in decarbonizing other industries. Ideally, CO_2 does not need to be transported far to be either sequestered or used as a feedstock in other chemical processes. For example, acid gas injection could be completed throughout Western Alberta, and could be used in smaller-scale CCUS applications for nearby industries.

There are some situations where there are large emitters in concentrated regions and some distance to store or sequester these emissions. The Alberta government recently submitted a request for proposals for CCUS hubs in hopes of spurring large-scale economic development. We continue to believe that companies with experience in managing reservoirs represent the best candidates for the storage portion of applications; however, CCUS requires cooperation from those who capture, transport and also store (or use) the carbon produced from industrial processes and/or oil and gas production.

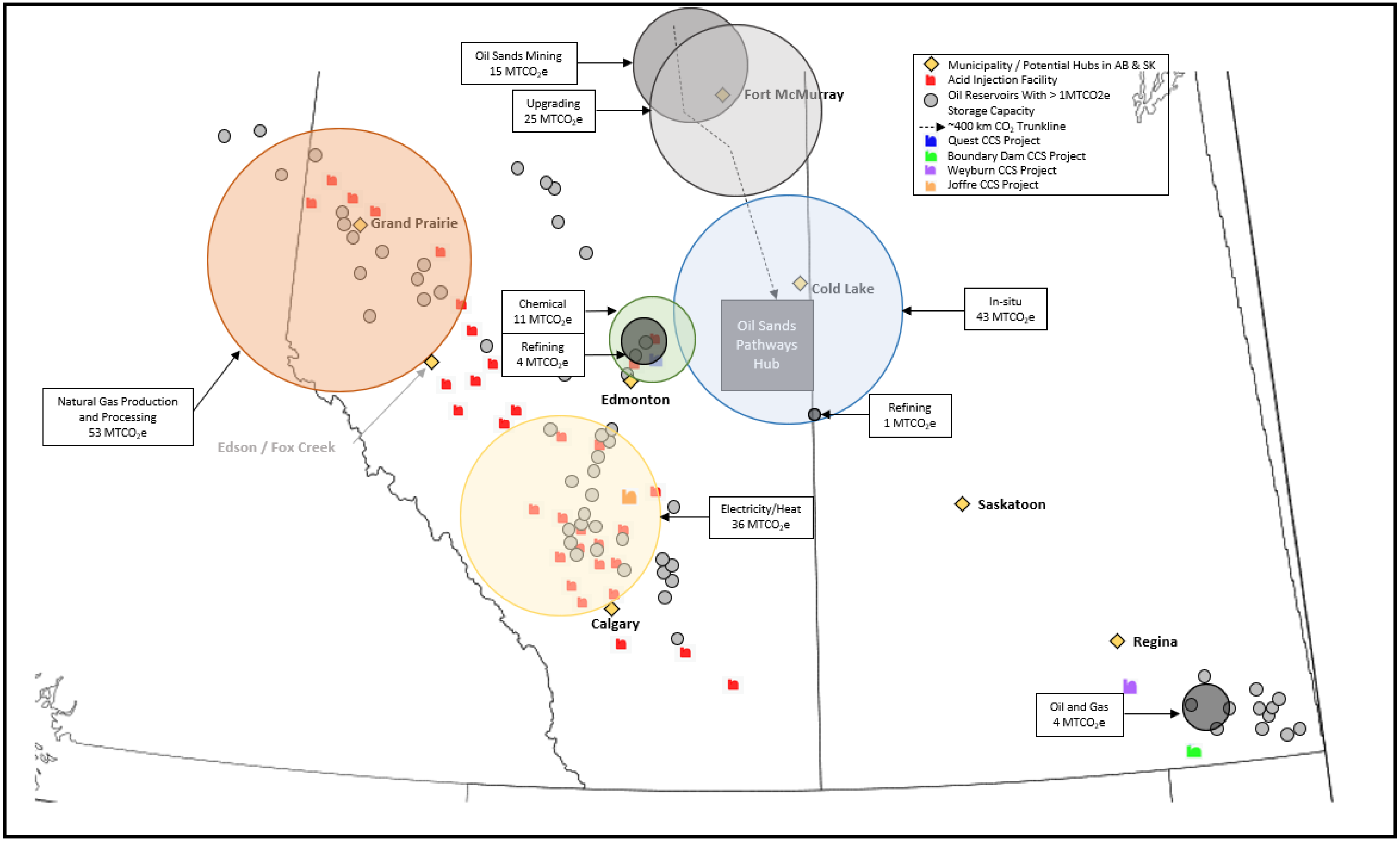
Some recent partnerships highlight the opportunity for oil and gas companies to help lower emissions from proximal industries. For example, Federated Co-op Ltd and Whitecap Resources signed Memoranda of Understanding (MOU) to develop a CCUS facility associated with a regional refinery; Nutrien signed agreements with Enhance Energy and Alberta Carbon Trunkline to sequester its CO_2 emissions and use it for enhanced oil recovery; and Keyera and Shell signed MOUs to explore opportunities to transport captured CO_2 to the proposed Polaris CCUS project. Recently, the Alberta government has also moved forward with the following six proposals for carbon hubs in the Industrial Heartland.

- The Meadowbrook Hub Project, by Bison Low Carbon Ventures Inc., for a potential sequestration hub north of Edmonton.
- The Open Access Wabamun Carbon Hub, by Enbridge Inc., for a potential sequestration hub west of Edmonton.
- The Origins Project, by Enhance Energy Inc., for a potential sequestration hub south of Edmonton.
- The Alberta Carbon Grid™, by Pembina Pipeline Corporation and TC Energy, for a potential sequestration hub north and northeast of Edmonton.
- The Atlas Carbon Sequestration Hub (Atlas Hub), by Shell Canada Limited, ATCO Energy Solutions Ltd. and Suncor Energy Inc., for a potential sequestration hub east of Edmonton.
- A proposal by Wolf Midstream and partners for a potential sequestration hub east of Edmonton.

Further requests for proposal on projects outside of that industrial corridor are expected to be submitted from April 25 to May 2. The map in Exhibit 11 highlights several regions of relatively concentrated industrial activity, oil reservoirs with significant potential storage capacity, and existing CCS projects. We view the ability to create hubs that connect the Fort McMurray oil sands mines and upgraders with the Cold Lake-centric in situ production, as well as projects helping capture and sequester carbon in the Alberta Heartland Industrial Complex just outside of Edmonton, as helping Canada achieve its climate targets.

Looking into the future, projects like the proposed ATCO/Suncor blue hydrogen facility could help decarbonize parts of the electrical grid, and post-combustion capture projects at oil sands facilities and refineries could further accelerate decarbonization of the resource.

Exhibit 11: Western Canada – Emissions By Source, Acid Injection Facilities, And CCUS Hubs, 2019



Source: Environment and Climate Change Canada, GeoSCOUT and CIBC World Markets Inc.

What Else Does Government Need To Do?

Canada must remain competitive to attract global capital. At our proposed tax credit level, we believe the first tranche of facilities would imply an opportunity cost for the government of ~$37/tonne. This falls well below the United States' 45Q program even before the potential revision with the Biden Administration's Build Back Better plan of US$50/tonne for storage in saline geologic formations (US$85/tonne if the Build Back Better amendments are implemented). It also falls short of the projects in Norway (Northern Lights) and the Netherlands (Porthos), which show government funding of CCS projects at ~$40 - $53/tonne. The table in Exhibit 12 highlights carbon pricing, emission reduction targets and CCUS subsidies by country for regions which could compete against Canada for capital.

Exhibit 12: Global – Government Support For CCUS Initiatives, Current

	Canada	United States	Australia	United Kingdom	Norway	Netherlands
Regulatory Support	Output-Based Pricing System Clean Fuel Regulation (Proposed)	45Q Tax Incentive	Emissions Reduction Fund Australian Renew. Energy Clean Energy Finance Corp.	CCUS Infrastructure Fund Economic Regulatory Regime	Longship	SDE++
Emissions Reduction Target	40%-45% reductions from 2005 levels by 2030	50%-52% reductions from 2005 levels by 2030	30%-38% reductions from 2005 levels by 2030	78% reductions from 1990 levels by 2035	50%-55% reductions from 1990 by 2030	55% reductions from 1990 levels by 2030
Net-zero Target	Net-zero emissions by 2050	Net-zero emissions by 2050	Net-zero emissions by 2050	Net-zero emissions by 2050	Net-zero emissions by 2050	Net-zero emissions by 2050
Carbon Pricing	$20/TCO2e in 2019 $50/TCO2e in 2022 $170/TCO2e in 2030	No carbon tax yet	No carbon tax yet	UK ETS Cap-and-trade system (Mirrors EU ETS)	EU ETS €60/TCO2e in 2021 €200/TCO2e in 2030	EU ETS €30/TCO2e in 2021 €125/TCO2e in 2030
CCUS Subsidies	Budget 2022 to reveal more details around investment tax credit for CCUS; EOR tax credit excluded	US$35/TCO2e for EOR US$50/TCO2e for storage	Government grants up to A$25 million for pilot / pre-commercial projects	£1 billion government support for CCUS development	€2.1 billion government support for CCUS development	€5 billion government support for CCUS development

Source: Government websites and CIBC World Markets Inc.

Provincial governments could top up tax credit incentives. We believe provincial governments are waiting for additional clarity from the Federal government on incentivizing carbon-capture projects before introducing additional legislation that could further promote capital deployment within their respective jurisdictions. Historically, we've seen combined incentives in projects like Shell's Quest and the SaskPower Boundary Dam facilities from both the Federal and Provincial (Alberta and Saskatchewan) governments.

Regulatory certainty is paramount. Regulatory risk in the oil and gas space has plagued investment and could derail spending on a net-zero solution. A framework for carbon price, CCUS tax credits or even standards around clean fuel that does not have support from all political parties could freeze capital deployment in critical infrastructure from the private sector. While price (specifically) of carbon is a risk that can be managed by companies through industry-level partnerships, material changes in legislation is too high of a risk for companies to move beyond initial engineering work on larger-ticket sustainability projects, without some level of assurances or backstops from the government.

This is not to say oil sands companies (or companies in general) will shy away from funding sustainability projects, but rather their focus will continue to be on maximizing returns while being mindful of compliance costs of doing business. We believe this could push oil sands operators to focus on debottlenecking operations to improve supply/operating costs and return cash to shareholders, rather than developing large-scale carbon-capture projects. We remain concerned that a government-decided price on carbon could significantly affect the primary source of revenue for CCUS projects and create significant uncertainty around these major capital projects.

Plans to implement a Clean Fuel Standard (CFS). The Clean Fuel Standard takes a lifecycle carbon intensity approach, taking into account the emissions from extraction through processing, distribution and end-use. The CFS complements the carbon pricing system, targeting how fuels are produced and used in Canada. The government expects the liquid-class Clean Fuel Standard will reduce GHG emissions by more than 20 MTPA in 2030. Under the CFS, the carbon intensity reduction requirement will start at 2.4 gCO2e/MJ in 2022, and gradually increase over time to 12 gCO2e/MJ in 2030, implying a 2030 absolute reduction target of 30 MMtpa. Companies able to exceed these targets could generate incremental credits, helping boost the economics of CCUS.

Pore space shouldn't be a hindrance for new projects. Securing a location to store captured carbon is also important despite its relatively lower cost in the CCUS vertical. We believe relatively open access to either saline aquifers or depleted oil reservoirs is paramount in moving forward with CCUS projects. Alberta has recently requested submissions for carbon-capture storage capacity and has delayed the timing of providing feedback given the overwhelming response. The following are important considerations related to pore space:

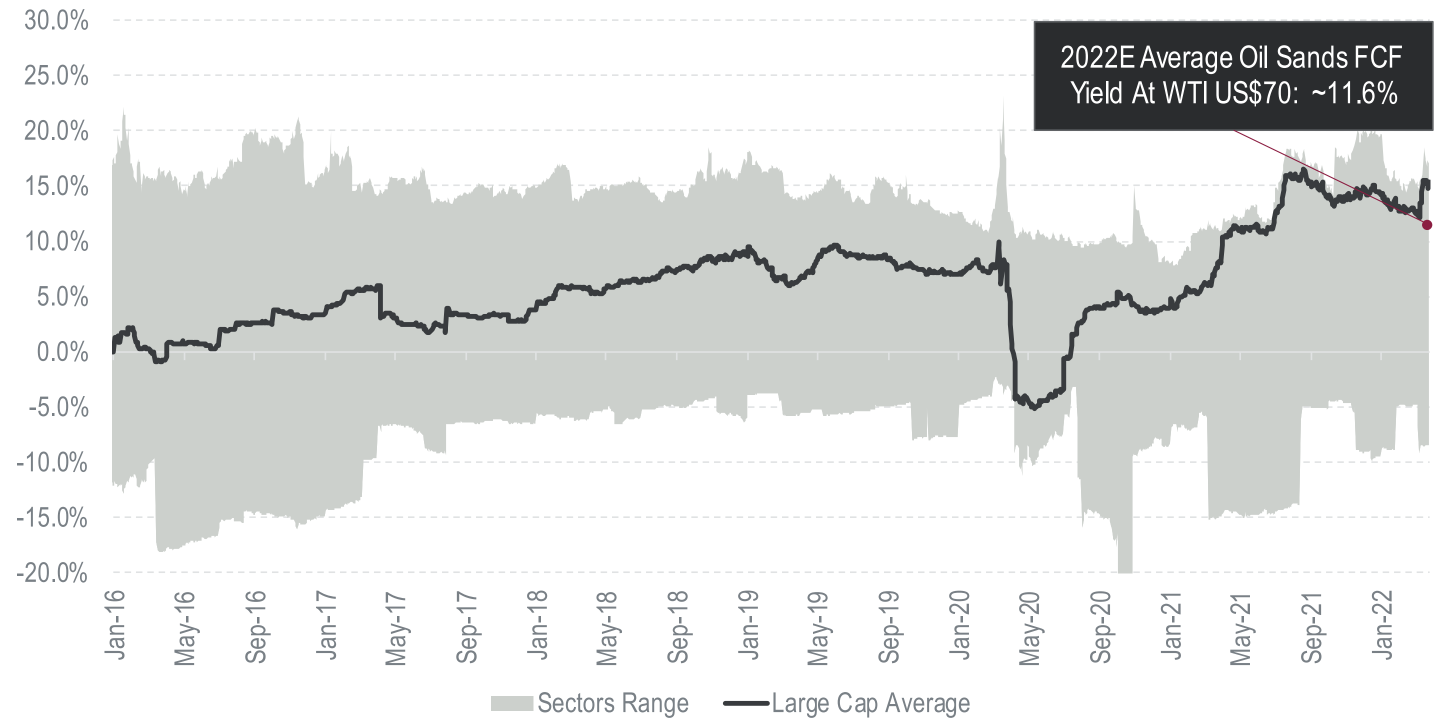
- Strong and significant financial capacity. In the case of an accidental release, we believe larger entities with cleaner balance sheets are better suited to manage the reservoir(s) and the liabilities associated with permanent carbon storage.
- Proven track record in reservoir management and/or demonstrated ability to continuously monitor the containment of CO_2 within the reservoir.
- Ensuring access is available to companies with interest in sequestering carbon at reasonable rates of return for the pore space holders, but not prohibitively expensive for the counter-party.

What Does This Mean For Canadian Energy?

The Canadian energy sector continues to trade at valuations that are below historical norms and its global peers. This is despite the return of WTI to ~US$100/Bbl and an environment for likely continued strength given a combination of underinvestment in the space and global geopolitical events. We believe the introduction of increased certainty in regulations surrounding carbon capture and its funding can help solidify the position of Canadian oil and gas as a vital and secure energy source while moderating concerns around energy transition, carbon intensity and perceived terminal value risk. Also, by providing financial incentives, the government can alleviate concerns about the financing of carbon-capture projects that show uncompetitive economics. We believe a combination of this certainty and moderation of concerns on funding CCUS projects could drive a narrowing of the significant valuation discount of Canadian oil and gas companies compared to their global peers.

Canadian energy companies are entering a period of harvesting free cash flow given the strength in commodity prices and an emphasis from shareholders away from production growth. Allocations of capital spending on material growth have ended, and these companies are in a period of harvesting cash flow (with decreasing sustaining capex requirements). We expect that excess free cash flow will be used to decrease current leverage and accelerate returns to shareholders, namely from buybacks given current valuations. The area chart in Exhibit 13 below highlights the historical valuation of companies within our space on EV-based FCF yield and the current valuation of equities today compared to global peers and other interest-rate-focused industries.

Exhibit 13: Energy – Canadian Oil Sands EV-based Free Cash Flow Yield (%) Vs. Interest-rate-focused Industries On Bloomberg Consensus, 2016 – Current



Note: Included Sectors - Oil & Gas (CDN / US / Super Major), CDN Midstream, Telecommunication, Utilities, and Mining

Source: Company reports and CIBC World Markets Inc.

Appendix: Carbon Capture And Sequestration Technologies

The four main applications of the conventional CO_2 capture technologies include pre-combustion, post-combustion, oxy-combustion, and chemical looping. There are four primary categories of carbon-capture technology: liquid absorption, solid adsorption, membranes, and cryogenic separation; each has a wide-ranging level of applications. These are conventional approaches related to the capture of CO_2 at the emissions source. We also highlight direct air capture (DAC), which enables the direct removal of CO_2 from the atmosphere. From our dive into the specific technologies, we have focused on liquid absorption as it is the most developed and has the highest chance of near-term application in major projects.

Primary Application Categories Of Carbon Capture

- **Pre-combustion.** This process refers to partially oxidizing hydrocarbon feedstock using steam and O_2 or air under high temperature and pressure to generate a mixture of CO, CO_2, and H_2, commonly known as syngas. Carbon monoxide is converted into carbon dioxide in a reaction called a water-gas shift. CO_2 is captured from the syngas before the hydrogen is combusted.

- **Post-combustion.** This process involves stripping carbon dioxide from combustion exhaust gases (flue gas). CO_2 can be captured using a liquid solvent or other separation methods. Capturing CO_2 in exhaust gases is typically completed at atmospheric pressure and could result in the presence of contaminants.

- **Oxy-combustion.** Oxy-combustion (or oxy-fuel combustion) involves the combustion of fossil fuels using pure oxygen (air is ~21% oxygen) to yield a high-concentration carbon and water flue gas stream. This application is currently at a large prototype or pre-demonstration stage, with a number of projects having been completed in coal-based power generation and in cement production.

- **Chemical looping.** This process involves a two-reactor technology. This technology uses a metallic oxide to produce energy instead of a fossil fuel. Unlike conventional oxy-combustion systems, the chemical looping process does not need an air-separation unit to supply oxygen for combustion, resulting in a relatively lower capital cost. Chemical looping has been developed by academia, research organizations and several companies, including manufacturers operating in the power sector. There are ~35 pilot projects with capacity up to 3 MW for coal, gas, oil and biomass combustion being developed and in operation.

Categories Of Technology For Carbon Capture

- **Absorption.** Carbon (CO_2) molecules are absorbed into a liquid or solid. This is an assimilation of molecules into the bulk of the solid or liquid (the adsorbent).

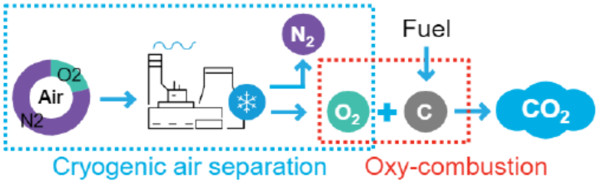
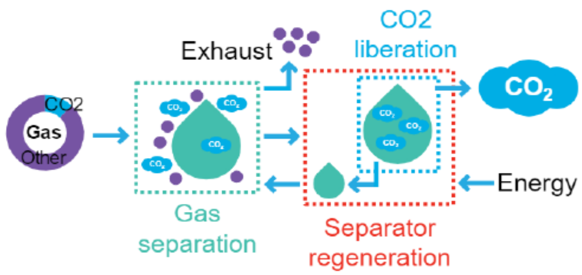
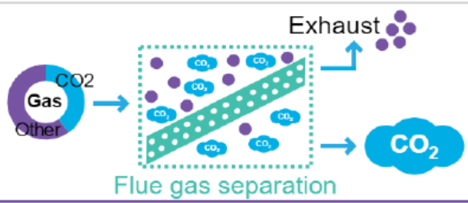
- **Adsorption.** CO_2 molecules adhere to the surface of the adsorbent (traditionally a solid). A film of the adsorbed material is created on the surface of the bulk material rather than in it.

- **Membrane.** A process where CO_2 molecules are selectively allowed to pass through a “filter” or membrane while retaining other gases contained within the product stream. The CO_2 is then collected.

- **Other.** We view this as some combination of the above three categories of carbon capture.

The table in Exhibit 14 shows a high-level explanation of the most common technologies for carbon capturing and their relative cost to retrofit.

Exhibit 14: CCUS – CO_2 Capture Technologies, Current

Type	Diagram	Explanation	When	Retrofit
Oxy-combustion		Fuel is burned in pure O2 to create high concentration CO2 Requires air-tight combustion environments The output gas is dehydrated (by cooling) and compressed	Pre-process	$$$
Liquid absorption		CO2-containing gases pass over reactive liquid absorbents, solid adsorbents or CaO granules CO2 is absorbed in liquids, adheres to solid surfaces, or reacts with CaO to form CaCO3 Additional energy is used to liberate CO2 from the separator and regenerate it for reuse	Pre- or post-process	$
Solid adsorption			Pre- or post-process	$
CaO looping			Post-process	$$
Membrane		Medium or high concentration CO2 streams pass over membranes that only allow CO2 to pass through Usually requires further CO2 purification using cryogenics to prepare it for transport	Pre- or post-process	$$$

Source: BNEF.

Major Considerations In Technology Selection

1) **Energy penalty.** The amount of heat energy required to facilitate the capture of CO_2 and regenerate the solvent. This can manifest into a parasitic draw on energy production from power plants or increased “heat load” for facilities. Energy penalty is one of the most important considerations that can impact project capex, operating costs and equipment sizing. Liquid absorption is the benchmark carbon-capture technology currently commercially viable in the industry; its energy penalty of ~0.2 to 0.5 MWh per $kgCO_2e$ is equivalent to 20% to 30% of power plant output. We view the energy penalty as being a limiting factor for new CCUS projects.

2) **System capacity.** Facilities are designed to run at certain specifications. It is important to ensure that equipment from piping to pumps, heat exchangers and tower sizing are optimized and appropriate for the expected capacity of solvent and the outlined carbon capture. Given the relatively under-tested scale of projects capturing at the megatonne level, we view the optimization of this sized facility as being a significant risk when deploying capital.

3) **Solvent loss/efficiency.** Arguably one of the largest operating/sustaining costs of CCS is in maintaining the efficiency of solvents used within the cyclical process. Given the range of temperatures in normal operations, solvent degradation and replacement represents a significant potential cost or implication in solvent and/or additive selection.

4) **Presence of contaminants.** An offshoot of solvent loss/efficiency involves the impact of impurities that inhibit the capture of carbon, like oxygen. Optimization of solvent selection and respective additives for the specific application is an important first step.

5) **Corrosion.** Operations that combine CO_2, water (H_2O) and oxygen (O_2) are susceptible to corrosion. Selection of equipment materials can impact capital costs and sustaining costs over the life of the project.

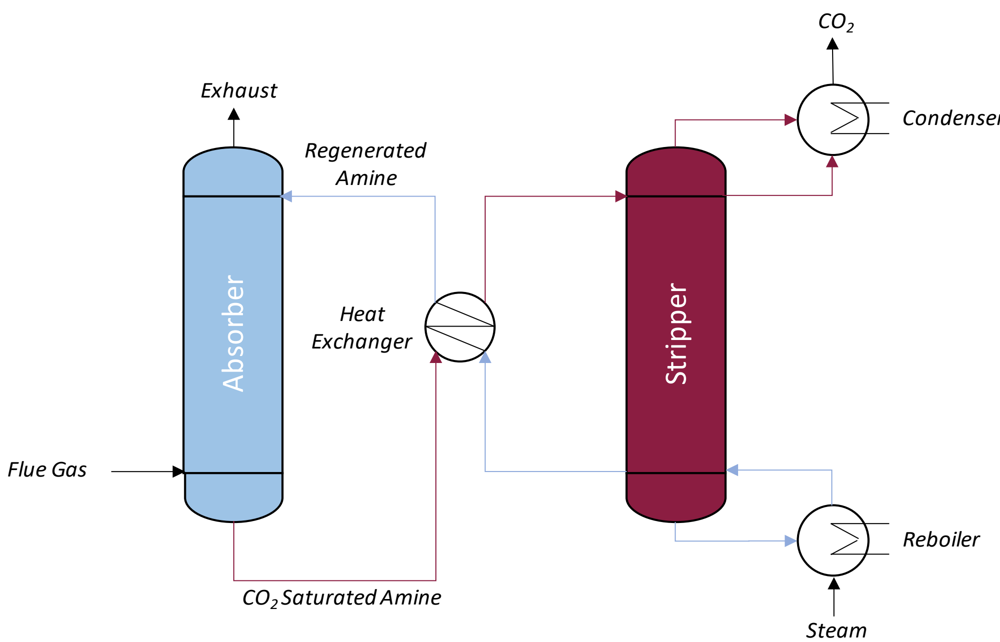
Liquid Absorption

Technology Overview

The most commonly used extraction technique for CO_2 within the oil and gas industry uses amine-based liquid solvents. This technique involves contacting the CO_2-laden gas with a liquid (lean) solvent in a tower. CO_2 is pulled from the product stream into the amine solvent in tall contacting towers. Later, this (rich) solvent is regenerated by heating it, liberating the CO_2 into a high-concentration stream, where the CO_2 is eventually sequestered in a reservoir.

Major considerations for solvent selection involve the concentration of CO_2 in the product stream, the presence of absorption inhibitors (like oxygen), the pressure of the product stream, absorption rate, capacity, heat of absorption, and maximum temperature from thermal solvent degradation. The best solvents are able to balance a combination of easily pulling CO_2 out of the product stream and then when little heat energy is added a quick release of the CO_2 into the disposal stream. The image in Exhibit 15 shows a simplified schematic diagram of liquid absorption.

Exhibit 15: CCUS – Simplified Liquid Absorption Process



Source: CIBC World Markets Inc.

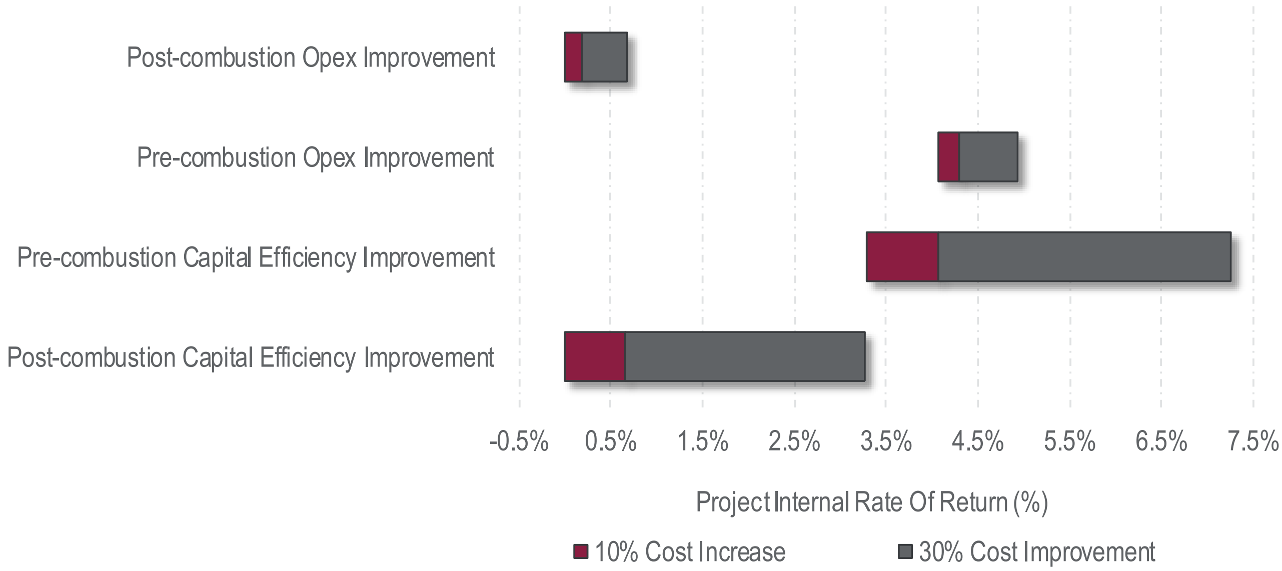
Milestones

This technology is already being commercialized at smaller scales (given the proliferation of sour natural gas processing facilities) and at two larger applications at Shell's Quest facility and the SaskPower Boundary Dam CCUS project. Further milestones with respect to liquid absorption would be driven by improvements in the solvent and further combinations of additives that help moderate the impact of CO_2 extraction inhibitors and/or improve the efficiency of extraction, such as Entropy's project at Glacier.

Liquid Absorption Economics

If there is a ~25% improvement in capital efficiency of carbon capture, we believe this technology is viable for pre-combustion applications at a larger scale. For post-combustion, we estimate there is a ~70% improvement needed for capital efficiency. The bar chart in Exhibit 16 highlights the internal rate of return of pre-combustion and post-combustion projects at different pricing scenarios.

Exhibit 16: CCUS – Capital Efficiency And Operating Expense Scenario Analysis, 2023E - 2052E



Source: Company reports and CIBC World Markets Inc.

Liquid Absorption Notable Projects:

1) CANSOLV - SaskPower Boundary Dam Unit 3 (BD3). SaskPower's BD3 CCS Facility is a fully integrated and full-chain CCS facility on a coal-fired power plant. The plant was completed in 2014 with a design capacity of 1 MMtpa. From October 2014 to October 2020, the facility captured 3.6 million tonnes of $CO_{2,}$ underperforming design capacity. The CO_2 is captured from and transported ~70 kilometers by pipeline for utilization in the CO_2-EOR operation at the Weyburn oilfield or into the Aquistore well (a deep saline CO_2 storage injection well).

CANSOLV is an amine-based system used to capture ~99% of the CO_2 from post-combustion and low-pressure off-gases. The system is widely adaptable in many hard-to-abate sectors with streams consisting of 3%-25%+ of CO_2 and offers the flexibility of being retrofitted as a tail-end system at power plants.

2) ADIP-X – Shell Quest. Quest uses ADIP-X technology to capture CO_2 from three hydrogen manufacturing units (HMU) at Scotford. Approximately ~80% of the CO_2 (or ~1 MMtpa of CO_2) produced in the reformer is removed from the raw hydrogen (Syngas) in an amine absorber. The captured CO_2 is then dehydrated and compressed prior to entering the pipeline system and injected into underground storage ~2 km below the surface.

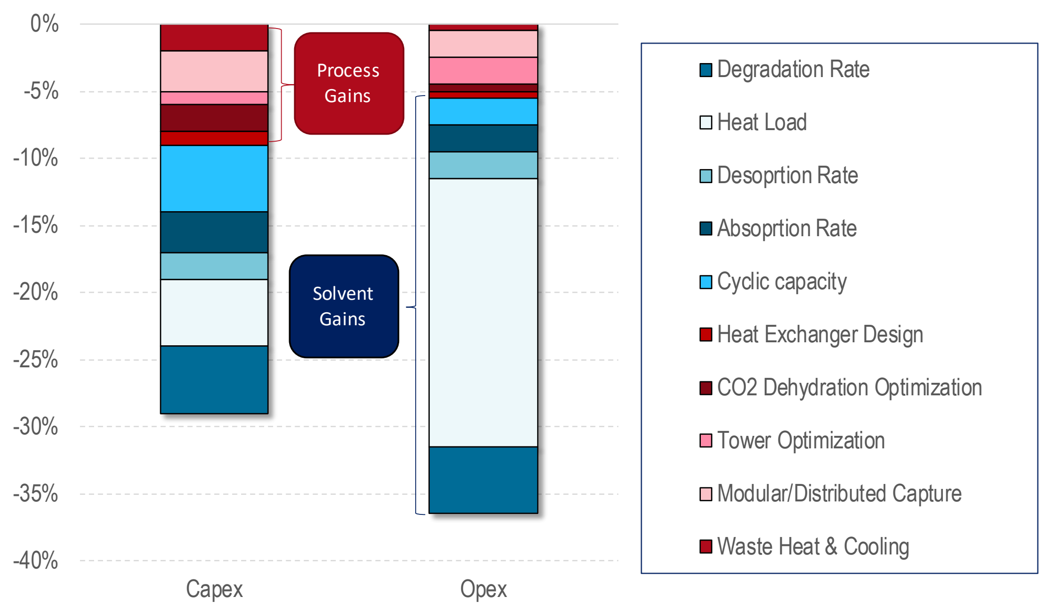
ADIP-X is typically used to capture CO_2 from high-pressure process streams. The technology is widely used across the globe, deployed at over 500 Shell and non-Shell sites. ADIP-X utilizes two amines, namely MDEA (methyl diethanolamine) as the main reactant and piperazine as the accelerator, which helps improve efficiency and reduce fouling, corrosion and solvent degradation.

3) Entropy23™ : Modular Carbon Capture - Entropy Inc. Entropy was created in 2021 and is presently 90% owned by Advantage Energy Ltd. (AAV) and 10% by Allardyce Bower Consulting (ABC). The company recently announced a new agreement with Brookfield Renewable, which will take a hybrid investment in Entropy and gain ~50% ownership in Entropy over time. Entropy draws on the knowledge of Advantage's acid gas injection scheme at its Glacier gas plant, which has been in operation for more than a decade for pre-combustion carbon capture and sequestration, along with the gas process engineering expertise of ABC. Entropy has also partnered with the University of Regina and the Clean

Energy Technologies Research Institute (CETRI), which has provided Entropy with exclusive rights to a proprietary solvent named Entropy23™. Entropy23™ is not only more efficient in removing acid gas from the stripping process, but it also recovers ~90% of carbon emissions, substantially reducing energy costs, operating costs and equipment capital requirements.

Early-stage technology with potentially wide application underpinned by impressive solvent technology. Entropy's carbon-capture technology targets cost reductions from comparable CCUS designs through process efficiency gains and superior solvent technology. The levelized cost of carbon capture for Entropy is expected to be <$50/tonne in most instances, making its technology one of the most economic at current carbon pricing. The base case expectations for efficiency gains from Entropy vs. a modelled analogue CCUS project are shown in the bar chart in Exhibit 17. Exhibit 17 highlights the anticipated gains are primarily owing to the solvent technology, however, we do expect the entire process to be complementary. In order to demonstrate the efficiency of the company's process and solvent technology, Entropy will initially utilize MEA (monoethanolamine) for the first three months of operation at its Glacier Phase 1 facility, then transition to Entropy23™.

Exhibit 17: Entropy – Modelled Design Efficiencies Versus CCUS Analogue, Current

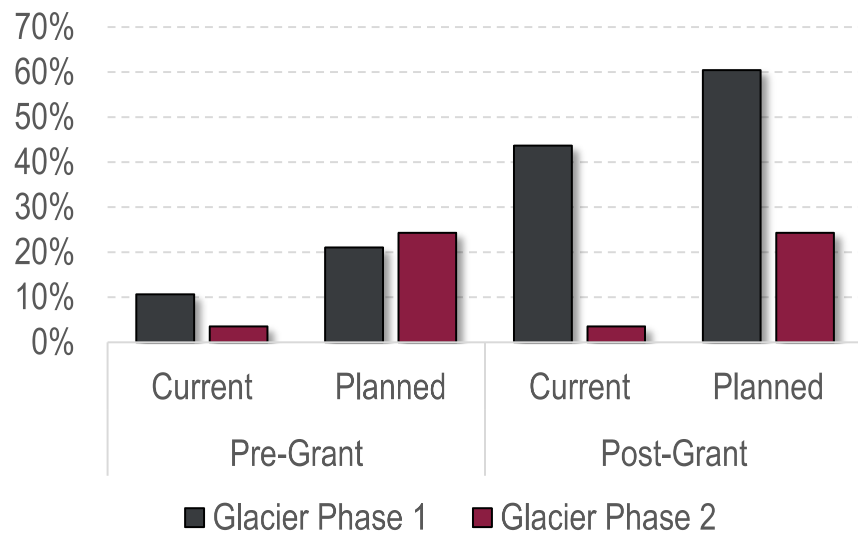


Source: Entropy and CIBC World Markets Inc.

Demonstration projects at Glacier will be under way shortly and the future project queue has intriguing potential. Entropy's current project queue includes the installation of carbon-capture technology on the Advantage Energy Glacier gas plant in north west Alberta, which should occur in three separate phases. Entropy's Glacier Phase 1 project has a total cost of $27 million and will capture 47,000 tCO_2e/year with an onstream date of Q2/22. Phase 1b should be in operation by Q1/23, targeting 16,000 tCO_2e/year at a project cost of $5 million. Phase 2 has a project cost of $49 million for capture of 136,000 tCO_2e/year with an onstream date of Q2/23. The total carbon capture potential of the Glacier project is up to 0.2 Mtpa, with an estimated breakeven carbon price ranging between $40/tonne and $60/tonne. The company also has numerous potential projects totalling more than 3 Mtpa at a Memorandum of Understanding (MOU) stage with third parties. From an economics perspective, Entropy's breakeven carbon pricing is estimated to be US$40/tonne on a levelized cost basis, which is economically more competitive than a number of deployed and future technologies.

Even though Entropy carries some of the lowest breakeven price points, economics are still relatively thin under current carbon pricing, implying the need for further government incentives and/or carbon price escalation. The bar chart in Exhibit 18 includes our estimated IRR for the Glacier Phase 1 and 2 projects under the current carbon price of $50/tonne ("Current") and planned pricing that escalates to $170/tonne by 2030 ("Planned"). We also include the impact of the $20 million in grant funding from the Alberta government, which nearly covers 75% of the Glacier Phase 1 project (no impact included on Glacier Phase 2). Most notable is that pre-tax returns under a pre-grant scenario are <15% for both projects at existing carbon prices of $50/tonne. This is a tough sell for energy companies that have a cost of capital >10% in most instances. Given Entropy is arguably the lowest-cost option around for carbon capture and sequestration, this provides a pretty clear demonstration that without government incentives, the economic motivation for companies to pursue carbon capture is likely to be subdued.

Exhibit 18: Entropy – Glacier CCUS Economics At Various Carbon Prices, Current



Source: Entropy presentation and CIBC World Markets Inc.

Solid Adsorption

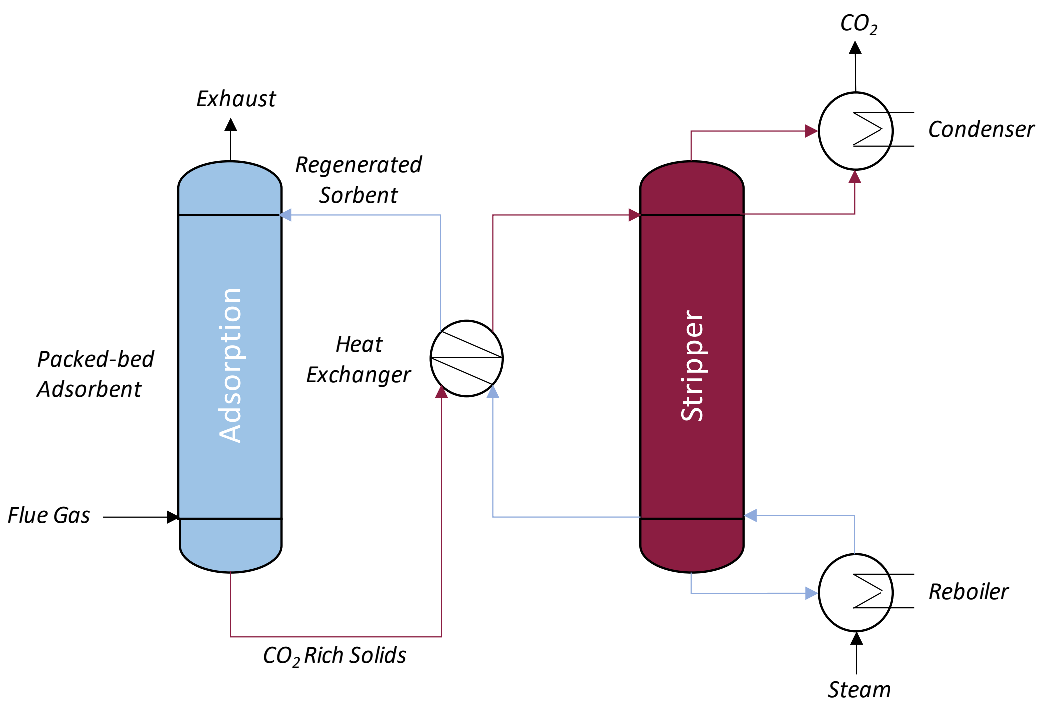
Technology Overview

In contrast to liquid absorption, where CO_2 molecules dissolve into the bulk material itself, the solid adsorption process, particularly fluidized bed or fixed bed, refers to the uptake of CO_2 molecules onto the surface of another material called sorbent. Solid sorbents selectively adsorb gas particles, which can be regenerated by heating the adsorbent or lowering the pressure to release the adsorbed CO_2.

On the other hand, the rotating bed adsorption process, developed by Svante Inc., is an efficient process to separate CO_2 from industrial flue gas. A moving bed or rotating bed adsorber (RBA) is composed of disc-shaped adsorbent sheets with parallel passages that are divided into four sections. The two sections or adsorption zone are exposed to flue gas for CO_2 adsorption while the heating zone is maintained under vacuum and the cooling zone cools the adsorbent for the next cycle.

The simplified process flow diagram in Exhibit 19 highlights the traditional fluidized bed adsorption process and the schematic in Exhibit 20 demonstrates the next-generation rotating bed adsorption process.

Exhibit 19: CCUS – Fluidized Bed Adsorption Process For CO_2 Capture



Source: CIBC World Markets Inc.

Solid Adsorption Milestones And Economics

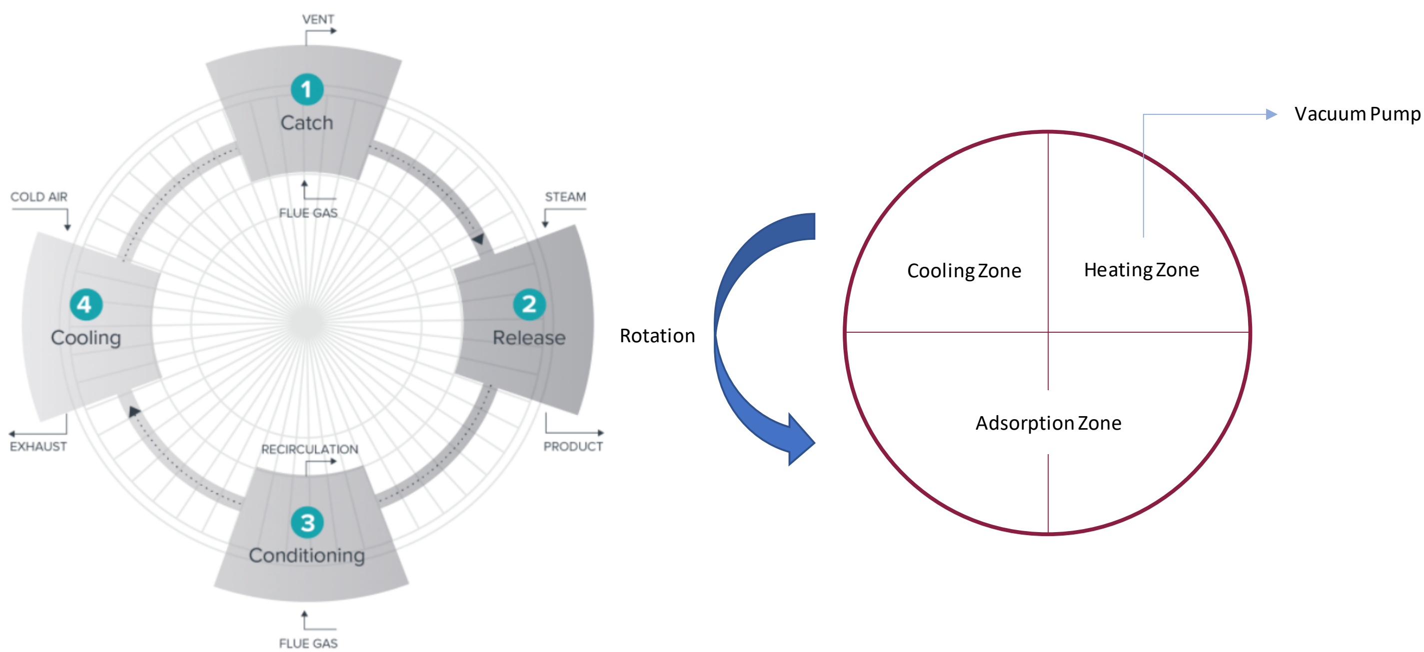
Solid adsorption is a newer technology. Solid sorbents have been used to remove CO_2 at low concentrations (<1%) from air in space shuttles and other manned space missions. Regenerable sorbents have been used since the 1990s in space shuttles and for the International Space Station. Hydrogen recovery at refineries is the most common application of sorbents in large gas-separation operations.

To advance sorbents as a viable at-scale CO_2 capture solution, research and development has been under way to demonstrate their low cost, thermal and chemical stability, resistance to attrition, low heat capacity, high CO_2 loading capacity, and high selectivity for CO2. Industry expectations is that there is a potential to reduce the cost of capture by 30% to 50%.

Solid Adsorption Notable Projects

Svante. The company offers a potentially commercially viable solution to capture large-scale CO_2 emissions from existing infrastructure. Svante has focused on developing proprietary solid sorbent materials, nano-filter, equipment and processes to efficiently capture CO_2 from the dilute (low CO_2 concentration) flue gas containing nitrogen of industrial plants and in the air. One of the purported advantages of this technology includes the rapid ability to adsorb and then release CO_2 (in less than 60 seconds), potentially lowering the initial capital cost requirements. The technology is currently being implemented at various locations of oil and gas and cement manufacturing plants; for example, at the CO_2MENT Pilot Plant Project, a partnership project between LafargeHolcim and Total S.A. Suncor and Cenovus, along with other industry players, are equity investors of Svante.

Exhibit 20: Svante – Rotating Bed Adsorption Process For CO_2 Capture



Source: Svante and CIBC World Markets Inc.

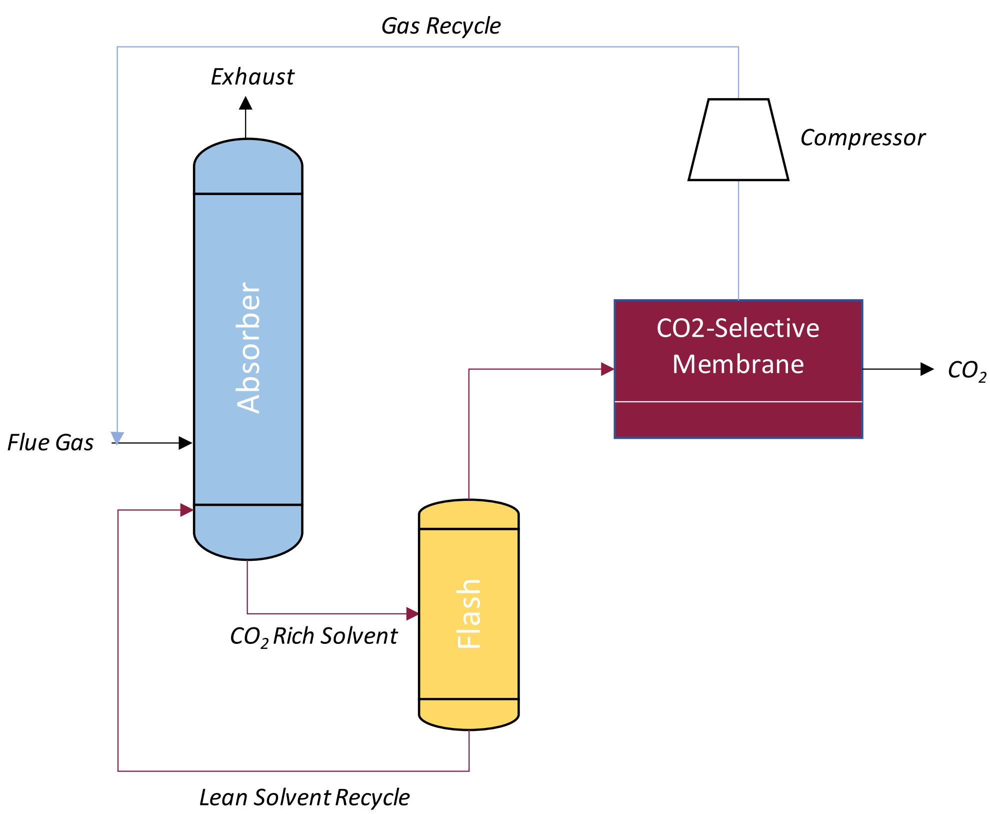
Membrane

Technology Overview

Membranes enable selective capture of CO_2 based on differences in solubility and diffusivity. The selectivity of the membrane to different gases is intimately related to the nature of the material, but the flow of gas through the membrane is typically driven by the pressure difference across the membrane. Membrane systems perform best when inlet pressures and the CO_2 concentrations are high (>90%) in the feed gas stream. Membrane separation, therefore, is more applicable to the pre-combustion capture process while it is quite challenging for post-combustion capture because of the low CO_2 partial and/or concentration in the post-combustion flue gases.

The simplified process flow diagram in Exhibit 21 highlights the CO_2 selective membrane technology.

Exhibit 21: CCUS – Membrane Process For CO_2 Capture



Source: CIBC World Markets Inc.

Membrane Milestones And Economics

Membrane technology is still in its infancy; it has not been widely adopted for carbon-capturing purposes, and is currently deployed in the natural gas processing sector at a demonstration stage. The only large-scale capture plant based on membrane separation is Petrobras' Santos Basin Pre-Salt Oil Field CCS facility, which uses membranes to capture CO_2 from offshore natural gas processing and reinjects it into the Lula, Sapinhoa and Lapa oil field for EOR (~4.6 MMtpa capacity). The technology has potential as it is scalable, compact and easily configurable for retrofit applications. According to industry estimates, the technology has the potential to reduce cost of capture by 30% to 50%.

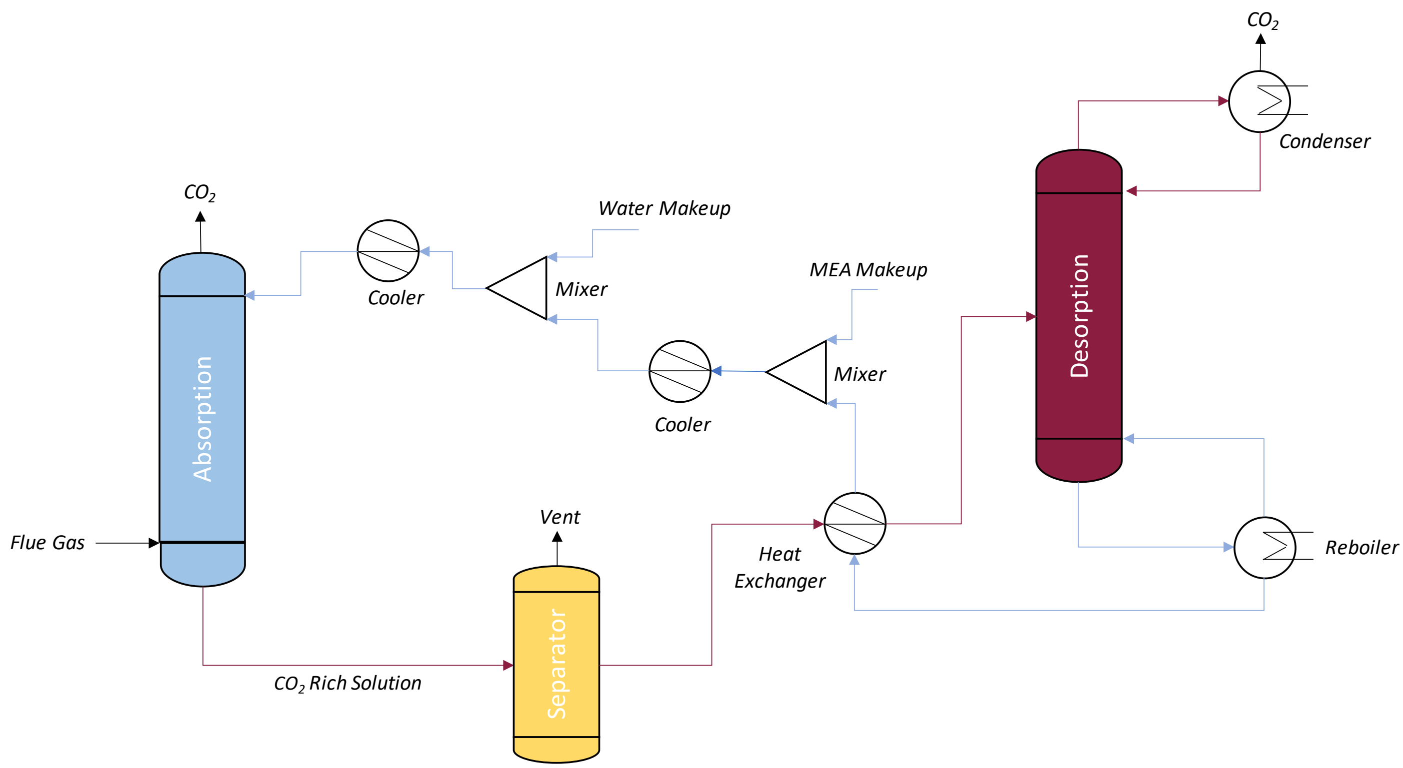
Cryogenic

Technology Overview

Cryogenic CO_2 capture refers to the separation of CO_2 from a gas stream by cooling that stream. The distillation is performed in a cryogenic chamber and the separation processes depend on the different boiling points of various gases. CO_2 can be separated as either a liquid or solid phase during cryogenic capture.

The simplified process flow diagram of cryogenic CO_2 capture technology is shown in Exhibit 22.

Exhibit 22: CCUS – Cryogenic Process For CO_2 Capture



Source: CIBC World Markets Inc.

Cryogenic Milestones and Economics.

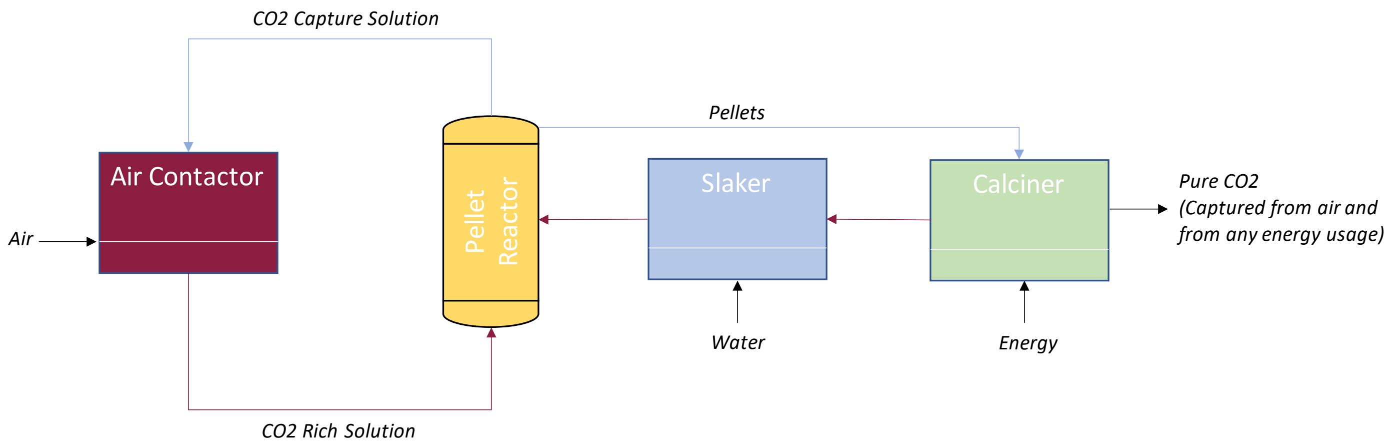
Cryogenic capture is a fairly new technology and, as such, many system integration activities and full demonstrations have not been tested at a meaningful scale.

Direct-Air Capture

Technology Overview

Direct-air capture (DAC) technology delivers negative emissions by capturing carbon dioxide directly from the atmosphere using liquid and solid DAC. Liquid systems directly allow air to pass through chemical solutions (e.g., a hydroxide solution), which removes the CO_2. The system reintegrates the chemicals back into the process by using high-temperature heat while returning the rest of the air to the environment. Solid systems use solid sorbent filters that chemically bind with CO_2. When the filters are heated and placed in a "vacuum" environment, the filters release absorbed CO_2, which can be captured for storage or use. A simplified diagram for OXY and Carbon Engineering's DAC project is shown in Exhibit 23.

Exhibit 23: CCUS – Direct-air Capture Process for CO_2 Capture



Source: CIBC World Markets Inc.

Milestones

DAC is a relatively new technology and requires much more research and pilot testing in order to be commercially viable, but it is one of the few technologies that is important to accelerate energy transition.

There are 19 DAC plants that are currently operational across the globe, mostly located in Europe, the U.S., and Canada. Most of the operational plants are small-scale and focused on selling captured CO_2 through carbonated drinks. Direct-air capture technology for large- and mega-scale plants is still in its infancy and industry leaders are currently in a developing stage. The first large-scale DAC plant is currently being built in the U.S. through the partnership between Occidental Petroleum and Carbon Engineering with a capturing capacity of 1 MMtpa of CO_2e that could become operational as early as 2024.

Economics

The cost of DAC technology can range from US$100 to US$1,000 per ton of CO_2 sequestered. The large variance in the capturing cost stems from small reference points (i.e., not many operational DAC plants), design efficiencies, and assumptions on energy consumptions. The table in Exhibit 24 highlights the cost estimates for direct-air capture technology from Carbon Engineering, Climeworks and Global Thermostat.

Exhibit 24: Carbon Capturing – Direct Capture Cost Per Tonne, 2018

Company	DAC Technology	Filter Type	Heating Temp. for CO_2 release (ºC)	Cost (US$/tonne CO_2)
Carbon Engineering	Liquid Solvent	N/A	900	$94-$232
Climeworks	Solid Sorbent	Amine-based	100	$600
Global Thermostat	Solid Sorbent	Amine-based	85-95	$90

Source: Company reports and CIBC World Markets Inc.

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