

# Carbon Capture, Utilization, and Storage in Newfoundland and Labrador: A Simple Analysis of Viability of CCUS Systems and Technologies in the Canadian Province of Newfoundland and Labrador

Robinson Tong

The Thacher School, Ojai, CA, USA  
Email: rtong@thacher.org

**Abstract**—Carbon Capture, Utilization and Storage (CCUS) is the only group of technologies that is known to decrease the amount of CO<sub>2</sub> in the Earth's biosphere, leading some experts to hail it as the cure for climate change. A significant number of CCUS projects have been implemented across the world and are being considered by many governments and policymakers, including the province of Newfoundland and Labrador. However, some are rightly skeptical of its perceived role as a cure for climate change. Through analyses of different CCUS technologies, the province's needs and resources, the risks associated with CCUS, and the economics and politics of CCUS in the province, we have concluded that Newfoundland and Labrador possess not just the capability of CCUS, but the potential of a major sequestration project. We highlight the need for more data to support simulations and modeling for more accurate assessment of specific CCUS implementation in Newfoundland and Labrador, as well as funding and incentives for emitters to participate in CCUS – in short, it is imperative that Newfoundland and Labrador steeply accelerate its planning, simulation, development, and implementation of CCUS.

**Keywords**—carbon capture, analysis of viability, CCUS (Carbon Capture, Utilization and Storage) systems

## I. INTRODUCTION

Carbon Capture, Utilization and Storage (CCUS) is a broad term that describes the process of capturing carbon dioxide (CO<sub>2</sub>) through various chemical or biological processes and utilizing it as a resource or sequestering it underground indefinitely. This group of technologies has gathered a lot of interest in the ongoing discussion of climate change – this is partly because CCUS possesses the unique ability to decrease the amount of already-released CO<sub>2</sub>, as opposed to other technologies which can only prevent CO<sub>2</sub> from entering the Earth's biosphere [1]. It holds promise as one of the technologies that could massively aid in pulling humanity out of our climate crisis.

Among those who are optimistic about the benefits of CCUS; environmentalist groups, petroleum companies, and governments, is the province of Newfoundland and Labrador. In 2022, Charlene Johnson, chief executive of Energy NL – a representative of Newfoundland and Labrador's energy sector – stated that the province had “so much potential” when it comes to CCUS. She states: “We have the opportunity to store more carbon than all that Canada produces. We know that through the seismic data that we have done looking for oil” [2].

However, as she suggests, this interest comes as an afterthought to the province's petroleum production – currently, there are no ongoing CCUS projects in Newfoundland and Labrador, nor are there any plans to begin one. Instead, the province is ramping up its petroleum production, investing billions into increasing the yield of fossil fuels [3]. Thankfully, as she also suggests, many aspects of the petroleum industry: surveying, modeling, injecting, infrastructure, etc. can also be utilized in similar aspects of CCUS – moreover, many sources of fossil fuels can act as storage sites for CO<sub>2</sub> [1]. Therefore, it seems that the province has untapped potential when it comes to CCUS.

With analyses of Newfoundland and Labrador's needs and capacities, we will discuss some possible suitable paths for CCUS development in Newfoundland and Labrador, as well as critical considerations for the future of both CCUS and environmental sustainability in the province and the world as a whole.

The IPCC, or the Intergovernmental Panel on Climate Change, presents scientific findings to governments relating to climate change. In 2005, the IPCC released a special report on Carbon Capture, Utilization, and Storage [1]. It outlines methods of carbon storage, the potential of the technology, as well as many issues needing resolution. The report states that CO<sub>2</sub> would be captured at points of concentrated release – fossil fuel power plants, large industrial centers, etc. – then transported to areas suitable for storage. Due to their relatively minimal nature, sources such as transportation and residences were not included in

the report. We will use these as bases to build our own report of CO<sub>2</sub> sequestration in the province of Newfoundland and Labrador.

## II. GLOBAL CARBON BUDGET

Before discussing carbon capture, one must first understand where and how carbon, primarily in the form of CO<sub>2</sub>, is released, and where it goes. We will discuss carbon dioxide, as CCUS captures carbon in that form. The vast majority of CO<sub>2</sub> originates from artificial sources such as energy production and industry, which accounts for roughly 40 Gigatons of CO<sub>2</sub> per year [4]. Artificially, CO<sub>2</sub> release is the result of primarily fossil fuel combustion. Though land and ocean absorb some (Fig. 1), a majority of CO<sub>2</sub> released is kept in the atmosphere [4].

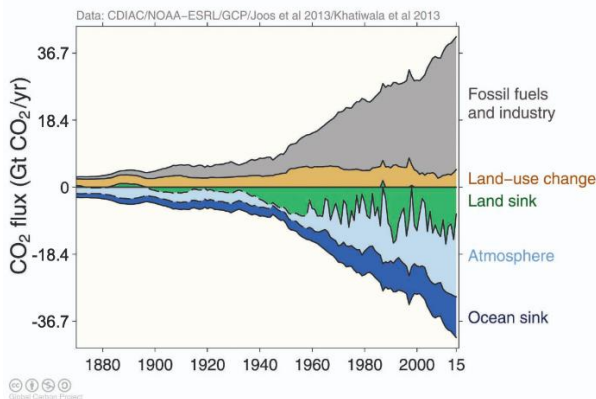


Fig. 1. An accounting of global carbon dioxide sources and sinks, modified ver. [4].

With these increased levels of CO<sub>2</sub> in the atmosphere comes the greenhouse effect. Just as a greenhouse traps the Sun’s heat with layers of glass, the atmosphere does the same with greenhouse gasses, of which CO<sub>2</sub> is a major contributor. Furthermore, the greenhouse effect destabilizes the Earth’s delicate climate, exacerbating meteorological extremes and causing climate crises like flooding, extreme storms, and wildfires. One cannot deny the effect that tens of gigatons of CO<sub>2</sub> released every year has on the Earth’s climate.

“Gigaton” is a unit that is very hard for humans to understand. One Gt, or one billion metric tons, is at a size near impossible for humans to visualize, but we can try. Take New York’s Central Park, with an area of 840 acres, or about 34.8 million square meters. Now imagine if you built a wall around the perimeter of the park the height of the Chrysler building, around 319 m – the walled-off prism that results would have a volume of about 1.03 billion square meters. If we somehow filled that box with water, the “pool” would weigh approximately one Gigaton.

With these numbers in mind, we can discuss the global carbon budget. The Paris Agreement aims to limit average global temperatures to 2 degrees centigrade, if not 1.5°C [5]; to achieve this goal, IPCC has estimated that, from 2020 onwards, cumulative emissions of around 500 Gt CO<sub>2</sub> result in 50% chance of reaching 1.5°C, and emissions of about 1400 Gt CO<sub>2</sub> result in 50% chance of reaching 2°C (Fig. 2) [1]. Our current rate of CO<sub>2</sub> emission

is 40 Gt of CO<sub>2</sub> per year [6]. At this rate, we will reach the 1.5°C benchmark by 2032, and the 2°C benchmark by 2055, not accounting for emission rate increase [6]. Even the best-case scenario would cause irreversible and devastating damage, so scientists urge governments to take action in combating CO<sub>2</sub> emissions and climate change. CCUS could slow – and even reverse – this process.

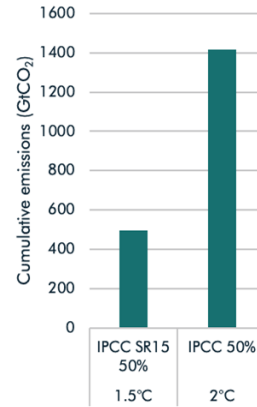


Fig. 2. Carbon budgets are smaller and/or have lower probabilities for 1.5°C than for higher-temperature outcomes [6].

## III. CAPTURE

The most common form of carbon capture is through photosynthesis. However, the compounds carbon is stored in are then utilized by the photosynthesizing organism itself or passed down the food chain, where CO<sub>2</sub> is released back into the atmosphere through respiration. Some processes store this energy indefinitely underground as fossil fuels. However, since these compounds are utilized for energy, this CO<sub>2</sub> is then released into the atmosphere yet again by combustion and other artificial processes.

BECCS – Bioenergy with Carbon Capture and Storage, combines organic sequestration with storage technology so that carbon captured by plants can be stored indefinitely, as opposed to natural and artificial processes which would release CO<sub>2</sub> back into the atmosphere [7]. Alternatively, there is a broad range of technologies that capture CO<sub>2</sub> artificially and convert it into liquid or solid form, where it then can be permanently stored underground.

One way of doing so involves placing carbon capture technology in stationary sources of emission, such as fossil fuel power plants or industrial facilities. The IPCC special report states that with current technologies, 85–95% of carbon emissions can be captured with pre and post-combustion systems, and the figure is around 90% with Oxyfuel systems, accounting for the removal of pollutants [1]. Near complete carbon capture is possible, although with larger and more energy-cost demanding systems. The report acknowledges that some efficiency of power production will be lost to carbon capture systems, along with increased waste generation and prices [1]. It should also be noted that this method only allows for net-zero emissions at best, as it can only capture what is being emitted by these industries.

Another process is Direct Air Capture (DAC), and the process works by capturing CO<sub>2</sub> directly from the atmosphere through various chemical processes. One method uses fans to draw air through a solution of potassium hydroxide and water, which bonds to CO<sub>2</sub> and separates it from the rest of the air. It is then converted to calcium carbonate after calcium hydroxide is added to the solution. This mixture is separated and converted into CO<sub>2</sub> again through a process called calcination – the CO<sub>2</sub> is then concentrated as a liquid and stored [8].

The process above is from a company called 1PointFive, subsidiary of Occidental Petroleum. Their DAC facility, STRATOS, still under development, is expected to begin operations in 2025. The company projects the facility's yearly capture to be approximately 0.5 Mt CO<sub>2</sub> [9]. In total, the International Energy Agency estimates a global capture capacity of 45 Mt CO<sub>2</sub> with 40 facilities in operation [9]. Retrofitting older plants would prove to be a challenge, so the IPCC report recommends designing new plants with CCUS systems in mind.

This may seem like a significant figure, but this figure is merely 0.125% of our annual emissions. Substantially more efforts need to be taken in order to make a noticeable difference. It is also important to note that many of these efforts are being funded and researched by oil companies, such as the previously mentioned Occidental. This may be for a myriad of reasons: Oil and petroleum companies have the money to fund such projects; they have many technologies used for resource extraction that could also be used for CCUS [10]; they have the incentive, being closely tied to the problem of excess atmospheric CO<sub>2</sub>, etc.

However, it is also important to acknowledge that, because carbon capture is often seen as a silver-bullet solution for climate change and emissions, these companies could be using this technology and their contributions to shed responsibility for decreasing emissions; as explained above, current contributions are very low compared to emissions. Therefore, more scrutiny should be placed on CCUS projects associated with petroleum companies and the impact they really have.

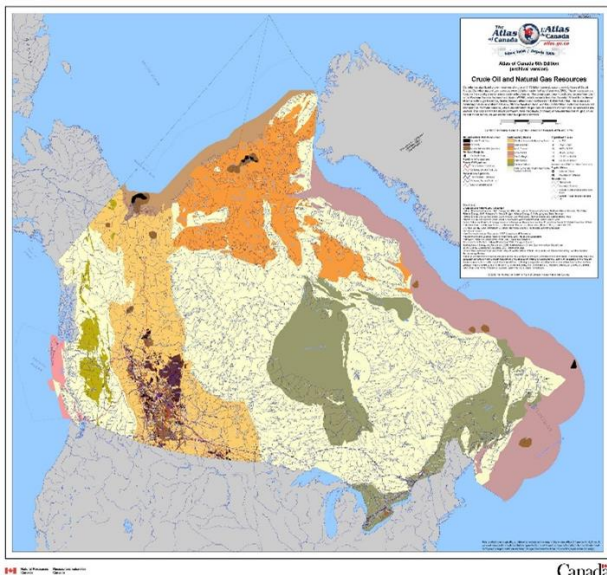


Fig. 3. Crude oil and natural gas resources [17].

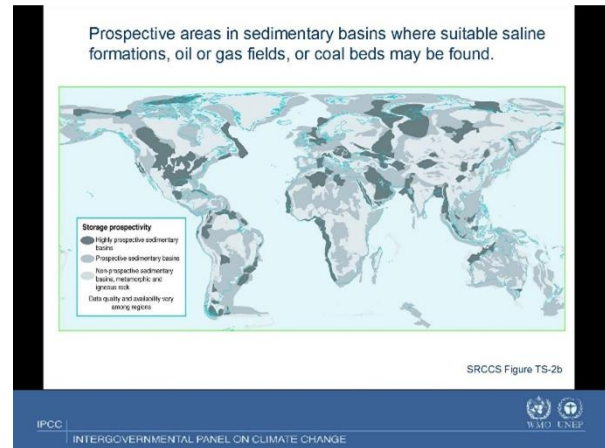


Fig. 4. Prospective areas in sedimentary basins where suitable saline formations, oil or gas fields, or coal beds may be found [1].

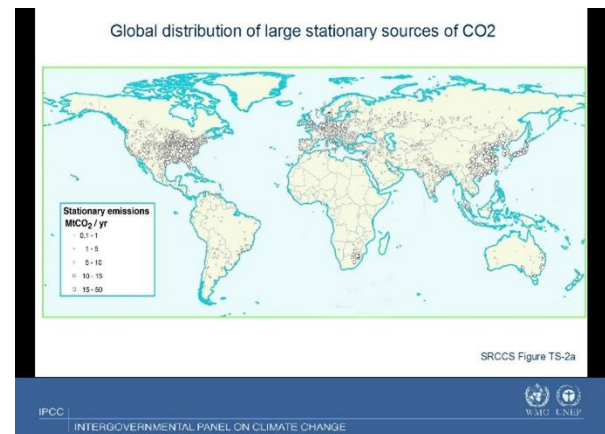


Fig. 5. Global distribution of large stationary sources of CO<sub>2</sub> [1].

The province of Newfoundland and Labrador doesn't emit much CO<sub>2</sub> compared to the rest of Canada – it emitted 9.5 Mt CO<sub>2</sub> in 2020 [11], 1.77% of Canada's total 534.9 Mt CO<sub>2</sub> emission in the same year [12]. However, Newfoundland and Labrador is the third largest producer of oil [11], and this is due to its proximity and ease of access to many fields and sedimentary basins off its coast (Fig. 3) [1]. The IPCC has identified these basins in the Labrador Sea as "Highly prospective (Fig. 4), the province has extensive petroleum extraction infrastructure in place, and the province does not produce much emissions within its borders, and the North American east coast has no shortage of major stationary emitters (Fig. 5); therefore, Newfoundland and Labrador could focus less on carbon removal, and instead utilize its basins for storage of CO<sub>2</sub> transported from elsewhere.

This is not a new concept. As Charlene Johnson stated, "[We don't] generate that much carbon, but [we can bring] it in from other jurisdictions like Norway does, or from other provinces, as well." One Norwegian project which fits her description is the Northern Lights project. Funded by Equinor, Shell, and Total [13], approved by the Norwegian government in 2021 [14], it is a part of the Longship project, the Norwegian government's own CCUS project [15]. Longship encompasses the complete value chain of CCUS, developing capture, transportation, and storage – Northern Lights, however, is responsible for

the transportation and storage of already-captured CO<sub>2</sub>, and it has extended past Longship's focus on Norwegian industries, planning to collect and transport CO<sub>2</sub> from other European countries (Fig. 6) and ship them to the North Sea, where they can be stored in offshore sequestration sites [16]. Because of the similarities in methodology to our proposed system, we will use this project as a loose basis for our recommendations going forward.



Fig. 6. Northern Lights designated a project of common interest by the European Union [16].

#### IV. TRANSPORTATION

In order to implement CCUS in Newfoundland and Labrador, we need to find a method to transport CO<sub>2</sub> to sequestration sites. Not only is CO<sub>2</sub> transportation already an established technology, many industries' active utilization has cultivated a wide array of efficient and cost-effective means. The IPCC report outlines three methods of carbon transport: ground transport, pipelines, and maritime shipment. Apart from small-scale operations, the report discourages transportation by rail or road due to its relative inefficiency [1].

The report hails pipelines as a more suitable system: it does not require lower temperatures needed by shipment or rail, as CO<sub>2</sub> is kept in a supercritical state; the compressed gaseous form used also allows CO<sub>2</sub> to be transported more efficiently [1]. Large-scale pipelines for CO<sub>2</sub> have been implemented, and are a proven system – currently, around 9500 km of CO<sub>2</sub> pipelines operate worldwide, mostly in the United States (International Energy Agency, n.d. b). They carry an estimated yearly 68 million metric tons of CO<sub>2</sub>, and a 2500 km pipeline in Texas has transported CO<sub>2</sub> since the 1970s for use in Enhanced Oil Recovery (EOR) [17].

EOR is a process in which CO<sub>2</sub> or other fluids are used to displace oil from underground wells. It has seen relatively widespread use, such as more than 100 examples in the US, and the CO<sub>2</sub> is expected to stay sequestered underground [18]. Consequently, the technology has seen

support by environmentalist groups, but the extractive nature of EOR makes it a contentious topic [18].

Pipelines are not without controversy themselves. In February 2020, a pipeline rupture in Mississippi caused the hospitalization of 45 from asphyxiation and other health effects [19]. The incident raises questions about the gaps in safety protocol and regulation of tens of thousands of kilometers' worth of pipelines. Moreover, pipelines hold a controversial history of cutting through the lands of native peoples and other established communities [20]. To draw CO<sub>2</sub> to Newfoundland and Labrador, a new pipeline system would need to be built on the North American east coast between major points of emission and sequestration sites in Canada, cutting through borders and communities. As seen with the Keystone XL pipeline cancellation in 2021, environmentalists and other groups would likely strongly object to such a project [20].

Instead, because the potential storage sites as discussed in the previous section are largely offshore, we would recommend the usage of maritime CO<sub>2</sub> shipment. Shipments face a similar problem to railway transport – though they are the cheapest option for distances of 1000 km and above (Fig. 7), the scale is limited by fewer use cases and lower demand [1]. However, because the process uses similar technology to the commercial transport of Liquefied Petroleum Gases, existing infrastructure and systems can be refitted and adjusted to accommodate higher cases of CCUS [10]. Extensive research has been conducted on the shipment of CO<sub>2</sub> by European and Far Eastern countries, and large-scale projects are already being considered by the EU, such as the aforementioned Northern Lights project.

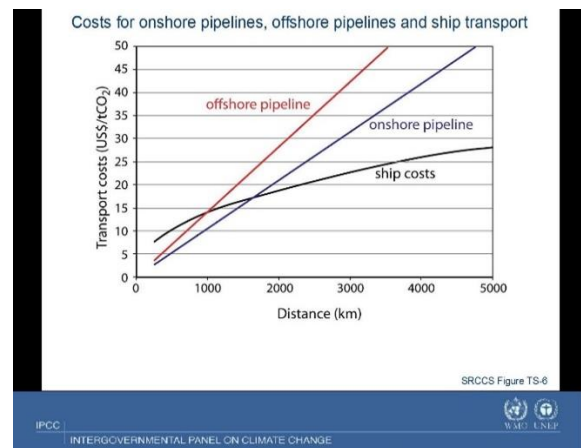


Fig. 7. Costs for onshore pipelines, offshore pipelines and ship transport [1].

A similar approach to this project can be adopted by Newfoundland and Labrador, where emissions would be collected from the North American east coast and shipped to offshore storage locations in the Labrador Sea and Atlantic. The previous transportation methods can be used to gather captured emissions from further inland. Building multiple, smaller-scale pipelines in tandem with utilizing maritime shipment could provide a safer, cheaper, and more ethical alternative to a longer inter Canadian-American pipeline.

The Northern Lights project utilizes two relatively smaller CO<sub>2</sub> tankers with a liquid CO<sub>2</sub> capacity of 7500 cubic meters [16]. With the average pressure of CO<sub>2</sub> kept at around 15 barg and at a temperature of about -30°C [21], we come to a figure of around 8000 metric tons per ship. The Longship project is set to transport 1.5 Megatons of CO<sub>2</sub> yearly [22]. This is a small figure in terms of total yearly emissions and global carbon capture. However, it is important to note that this is just one of many CO<sub>2</sub> ship transport projects in the world, so the global industry may make a more noticeable dent in yearly emissions. If a project of a similar scale were to be conducted in Newfoundland and Labrador, ships could transport one-sixth of the province's yearly emissions.

The IPCC report acknowledges risks associated with these forms of transport, including CO<sub>2</sub> leakage and accidents, but these are rare and controllable through overpressure protection, leak detection, and other measures. The report finds no major obstacle or risk to large-scale CO<sub>2</sub> transportation, apart from some of those experienced by related industries: hydrocarbon shipping, gas pipelines, etc. [1]. The technology will improve over time, and large scale adoption and development can help avoid incidents like that in Mississippi.

## V. STORAGE

For geological storage, the IPCC report mentions three types of storage sites: oil and gas reservoirs, deep saline formations, and unmineable coal beds (Fig. 8). The report states that many technologies, such as drilling, injection, and monitoring systems, can be used in CO<sub>2</sub> storage as well. For one, modeling and simulation software can be used to survey plausible storage sites; another example presents itself as diligent monitoring and testing to ensure safe storage [1].

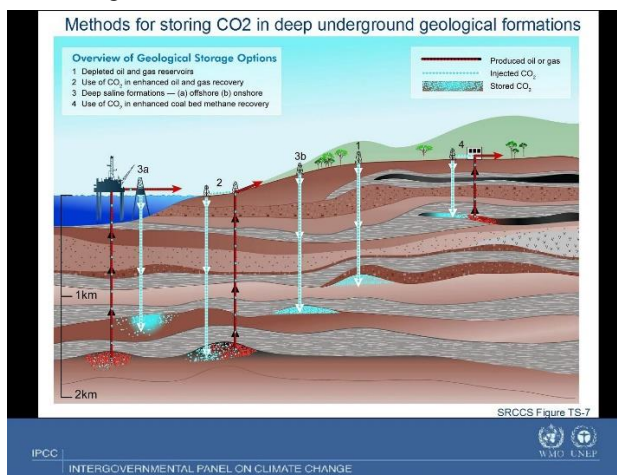


Fig. 8. Methods for storing CO<sub>2</sub> in deep underground geological formations [1].

The report states that because of underground conditions – storage taking place below 800 m, CO<sub>2</sub> being in a liquid state, and being 50-80% of the density of water – CO<sub>2</sub> will eventually try and find its way back up to the surface. Therefore, the report advocates strongly for the careful use of cap rocks (a layer of shale and clay) to

properly seal CO<sub>2</sub> away. It also advocates for the use of other mechanisms to achieve a similar effect [1].

Potentially, the report speculates, carbon stored in these formations can form carbonate minerals and be stored underground over millions of years, or the carbon can be absorbed by underground coal and shale deposits, staying underground for as long as conditions remain stable. Overall, though some legal and public perception issues need to be addressed, the report is optimistic about the credibility of geological CCUS [1].

Next, the report discusses oceanic carbon storage (Fig. 9). Though less well-studied as geological storage, smaller-scale experiments and models have proven that this method is viable, but delicate, and comes with more factors to consider than geological storage [1].

The ocean naturally absorbs atmospheric CO<sub>2</sub> over time, with estimates that 500 Gt CO<sub>2</sub> (approximately 40% of human emissions) had been absorbed in the past [1]. Additionally, the report states that there is no practical limit to the amount of CO<sub>2</sub> that can be stored in the ocean – therefore, injecting CO<sub>2</sub> into the water column can prove to be an effective means of CCUS. However, the report points out that the ocean's ecosystems could be at risk if oceanic CCUS is done irresponsibly; it advocates for a more mindful approach. Keeping oceanic-atmospheric CO<sub>2</sub> equilibrium in mind, the report projects that between 2,000 and 12,000 Gt CO<sub>2</sub> can be stored in the ocean [1].

With pools of liquid and solid CO<sub>2</sub> on the seafloor and alkaline minerals to counteract CO<sub>2</sub> acidity, the report estimates that the CO<sub>2</sub> can stay submerged for centuries, or even millennia. However, though not extensively studied, there have been reports of CO<sub>2</sub> having negative effects on marine organisms, and such high amounts of CO<sub>2</sub> could affect the ocean's ecosystems in yet unforeseen ways [1].

In addition, the report considers the potential for recycling or reusing released CO<sub>2</sub>. First, through a process of mineral carbonation (Fig. 10), carbon can be sealed in various alkaline-earth oxides, which can then be disposed of or used as raw material in construction. This process occurs naturally at a slow pace, but inducing it artificially requires potentially harmful mining operations, extensive monitoring, and exorbitant costs. Therefore, mineral carbonation is a riskier and yet unproven method of CCUS, and more research is required to prove its viability [1].

Secondly, the report considers the reuse of CO<sub>2</sub> in industry; many chemical and biological processes use CO<sub>2</sub> as a reactant, so CO<sub>2</sub> released as a byproduct can be taken advantage of. Uses include refrigeration, welding, carbonated beverages, fire extinguishers, and packaging. However, the report does note that CO<sub>2</sub> used in these processes is quickly released into the atmosphere, typically in days or weeks. Additionally, the small amount of CO<sub>2</sub> used in industrial processes compared to the total amount released would do little to help store away carbon long-term. The report even entertains the possibility of a net increase of CO<sub>2</sub> release if this method is pursued. In summary, the writers are doubtful of the benefits of CO<sub>2</sub> industrial re-use [1].

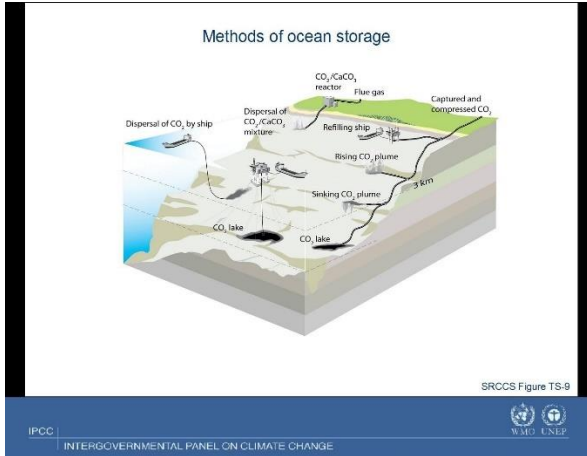


Fig. 9. Methods of ocean storage [1].

When approaching carbon storage in Newfoundland and Labrador, we will discuss geological storage. Not only is it safer for the environment if done correctly, it is also an already-proven method which has undergone relatively extensive research and implementation. Furthermore, Newfoundland and Labrador has an abundance of storage potential in the mostly offshore petroleum fields and sedimentary basins within its borders [1], along with already existing infrastructure like offshore platforms and pipeline technology that can be repurposed for CCUS [10].

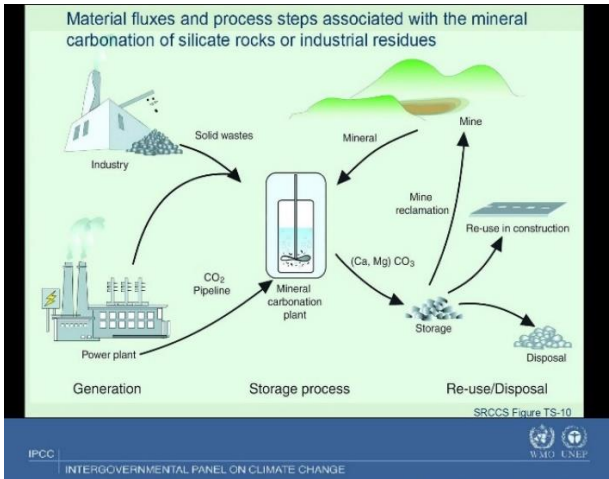


Fig. 10. Material fluxes and process steps associated with the mineral carbonation of silicate rocks or industrial residues [1].

We will try to loosely estimate the CO<sub>2</sub> storage capacity. To do so, one can utilize the “replacement principle,” in which the volume of oil or gas extracted from a field or region is approximately equal to the volume of CO<sub>2</sub> which can be stored [23]. Newfoundland and Labrador has extracted a total of “2 billion barrels of an estimated 3.3 billion barrels recoverable oil” according to the United States government, from four major projects: Hibernia, Terra Nova, White Rose, and Hebron [24]. Each barrel of crude oil converts to about 0.159 cubic meters, giving a total of around 524.7 million cubic meters (see below calculations) of estimated recoverable oil in Newfoundland and Labrador.

$$3.3e9 \cdot 0.159 = 524.7e6 \text{ m}^3$$

The Imperial College London uses 600 kg/m<sup>3</sup> for the density of CO<sub>2</sub> stored underground [25], meaning recoverable oil fields in Newfoundland and Labrador could hold 314.82 Mt CO<sub>2</sub> (see below calculations).

$$524.7e6 \text{ m}^3 \cdot 600 \frac{\text{kg}}{\text{m}^3} = 314.82e9 \text{ kg} \\ = 314.82 \text{ Mt CO}_2$$

The Canadian government estimates that around 356.7 billion cubic meters of exploitable natural gas lie in the borders of Newfoundland and Labrador [11]; using the replacement principle, Natural gas fields in Newfoundland and Labrador add 214.02 Gt CO<sub>2</sub> (see below calculations) to the province’s storage capacity.

$$356.7e9 \text{ m}^3 \cdot 600 \frac{\text{kg}}{\text{m}^3} = 214.02e12 \text{ kg} \\ = 214.02 \text{ Gt CO}_2$$

The final estimated capacity is around 214.33 Gt CO<sub>2</sub>.

## VI. SIMULATION

To more accurately calculate the capacity of different oil and gas fields, we can utilize computer simulation. For example, MATLAB’s Carbon Sequestration Model uses the MATLAB Reservoir Simulation Toolbox (MRST) [26] to model different carbon sequestration projects using data from their respective fields and geological formations.

The program’s developers provided 24 Norwegian oil and gas fields as examples, one of which is the Sleipner Gas Field of Equinor, which has pumped more than 15 Mt of CO<sub>2</sub> underground in 19 years since the project’s conception in 1996. According to Carbon Capture and Sequestration Technologies MIT, this project was the first example of commercial CCUS [27]. The model generated by MATLAB of the Sleipner gas field shown below (Fig. 11) includes a 3D visual representation of the storage site, as well as manipulatable factors such as CO<sub>2</sub> saturation, pressure deviation from Hydrostatic, etc. Models like this can be used to assess the viability of storage sites, evaluate injection points, and conduct tests of safety and longevity.

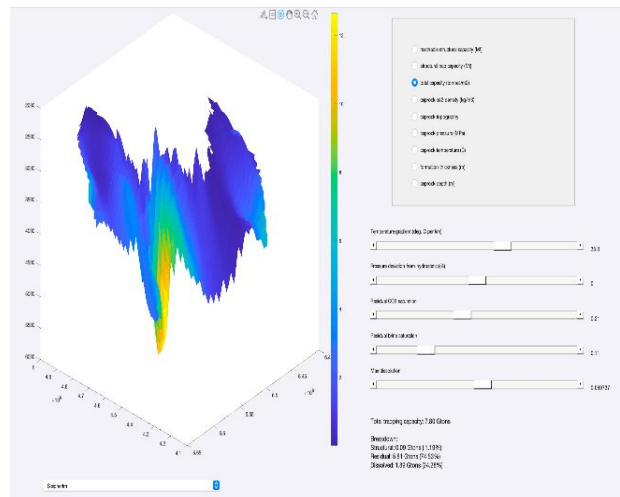


Fig. 11. Sleipner gas field example in MATLAB modeling tool.

The Norwegian Petroleum Directorate emphasizes the importance of gathering data and geological surveying in preparation of CCUS projects [28]. The Norwegian government has worked extensively with scientists and petroleum companies to produce a “CO<sub>2</sub> Atlas” of Norwegian oil fields, which has been used in the production of the MATLAB example models mentioned above [26]. However, to our knowledge, no similar dataset has been developed for Newfoundland and Labrador.

Canada has previously cooperated with the United States and Mexico in the production of the North American Carbon Storage Atlas, a data collection and assessment of potential carbon storage sites in North America, in 2012. However, storage sites in Newfoundland and Labrador were not included because of their distance from major stationary CO<sub>2</sub> emitters [17], nor were other sources found during the writing of this report. Nevertheless, according to the Norwegian Petroleum Directorate, much of the relevant data may be provided by petroleum and energy companies and government energy ministries, as data used to assess the extraction of resources in these fields is also applicable to assessing the viability of CCUS [28].

To best understand and prepare for a future CCUS project in Newfoundland and Labrador, geological data must be gathered from relevant sources and additional surveying, as well as made available to researchers so that modeling can be done and viability can be assessed more accurately.

## VII. ECONOMICS

Estimating the cost of a CCUS project without modeling will not yield accurate results; however, ongoing projects can give a rough basis. For the Northern Lights project, Equinor estimated in 2020 that initial investments would cost around 6.9 billion Norwegian crowns, or around 670 million US dollars, and would be provided mostly by Equinor, Shell, and Total [6]. This initial investment will be taken up mostly by construction and technological costs – subsequently, Northern Lights will acquire funds through charging CO<sub>2</sub>-emitting companies to collect already-captured CO<sub>2</sub> and store it underground [15]. In this way, Northern Lights is an “open-source” CCUS project, allowing emitting companies to adopt CCUS at their own pace and levels.

CCUS projects being spearheaded by major emitters – petroleum companies, energy plants, material producers, etc. – are a result of governments across the world providing incentives to do so. This comes in the form of tax cuts, financial agreements, and fines or other penalties [29]. The European emission standards and incentives are generally more pronounced than their North American equivalents, so companies operating in Europe are compelled to invest more in CCUS [30].

If a system of CCUS similar to that of Northern Lights were to be implemented on the North American East Coast, initial investment would mostly be at a similar scale. However, we would advocate for stronger government involvement in CCUS, to compensate for relatively weaker emission control in North America.

Firstly, initial funding may need to come from the government. The initial cost of Northern Lights is 6.8% of Newfoundland and Labrador’s estimated spending for 2023–24 [31], and just above 0.01% of Canada and America’s combined spending [32, 33].

Secondly, the governments of Canada and America will need to provide strong continuous incentives for emitters to participate in this project, if not requirements to do so. As the IPCC states, though the costs of CCUS are site and case-specific, the majority of costs will come from carbon capture. Estimates of energy price increase resulting from carbon capture costs range from 35–70% for Natural Gas Combined Cycle plants, 40–85% for supercritical coal plants, and 20–55% for Integrated Gasification Combined Cycle plants [1]. These costs may be transferred to the consumers and decrease demand. Therefore, without incentive or aid, major emitters in North America will be unlikely to invest in carbon capture systems.

The IPCC report also recognizes that as research progresses and technology improves, these systems will become cheaper – 20–30% over the next decade, the report claims, depending on R&D and commercial adoption of this technology [1]. However, without adequate political backing, adoption will not reach necessary levels in North America.

## VIII. POLITICS

As a petroleum-exporting state, Newfoundland and Labrador is also exporting its carbon footprint elsewhere. Though its carbon emissions are relatively low, it still has an obligation to pursue carbon-decreasing measures. Petroleum is 25% of its GDP and 41% of its exports [3]; so instead of limiting the province’s main industry, CCUS could be a good way of heading towards net-zero, as a temporary crutch to reach carbon limiting benchmarks while the economy moves away from petroleum.

However, CCUS should not be seen as a cure-all. Even if all emissions from petroleum and industries are collected and sequestered through CCUS, these resources are non-renewable and will eventually be depleted. Additionally, as seen in this report, the current scale of CCUS is nowhere near enough to support unrestricted fossil fuel use. The world needs to move towards renewables in order to achieve a stable future of energy. Instead of trying to capture the entirety of CO<sub>2</sub> emitted by the world with CCUS, it should be seen as a way to achieve net-negative emissions – only after initial emission reduction goals have been achieved.

According to the IPCC’s Special Report on Emission Scenarios, fossil fuel industries in the developed world are projected to stagnate while emissions from the developing world will grow exponentially [34]. The former has an obligation to offset emissions of the latter – the developed world has had the luxury of growing their economies by exploiting the planet’s limited resources, giving them a significant advantage during the necessary transition to renewables. Additionally, some developed countries are exporting emissions to other countries by shifting manufacturing to emerging economies, adding to their obligation to offset emissions.

Before renewables become the most economical sources of energy, the developing world will need to rely on petroleum and emissions to develop, making some CO<sub>2</sub> emissions unavoidable. Moreover, some critical products such as plastics, asphalt, lubricants, etc. are derived from petroleum – accounting for around 10% of global petroleum consumption – the production of which will also require some necessary emissions.

Developed countries cannot expect developing economies to prioritize the environment over their basic economic development. Instead, the developed world should compensate by becoming net-negative; offsetting necessary emissions while also letting those less fortunate naturally develop. They can do so by transitioning fully to net-zero economies, proliferating CCUS, and investing their relatively abundant resources to its development. In the future, if CCUS systems are developed enough, CCUS can also return atmospheric CO<sub>2</sub> to pre-industrial levels. As a developed nation, Canada can further its contributions by investing in CCUS, in Newfoundland and Labrador or otherwise.

## IX. CONCLUSION

CCUS is an important tool for mitigating the climate crisis the Earth is facing today, which the Canadian province of Newfoundland and Labrador is especially equipped to utilize, as a combination of government interest, existing infrastructure, and abundant storage site potential signifies.

To account for Newfoundland and Labrador's low emissions, captured CO<sub>2</sub> can be transported from large stationary sources on the North American east coast through maritime shipment, due to its economical advantage, lower ethics, and safety concerns, as well as the abundance of offshore storage sites which the province possesses. From there, storage could take place from refitted offshore platforms, into already-surveyed storage sites, using existing technology from the petroleum industry.

But to do so, investment must be placed in CCUS development, and researchers and relevant parties need surveying data to conduct simulation and modeling. Though the province has demonstrated some interest in CCUS, its current focus resides solely in expanding its petroleum industry, a path that many producers are going down. However, this is ultimately unsustainable, and Newfoundland and Labrador, just like all other producers of fossil fuels, will eventually have to significantly decrease and reorganize its petroleum industries. During the transition to renewable energy, CCUS will be a temporary yet necessary crutch to help its economy decrease its carbon at a more gradual rate than non-petroleum-based economies.

Major carbon policy changes will need to take place for these technologies to be implemented, as well as potentially hundreds of millions in initial investment and funding – however, with effective carbon-tax and incentive programs, a CCUS project can be self-sustaining and even profitable, such as the Northern Lights project

operating in Europe. It is not difficult to imagine Newfoundland and Labrador taking a role similar to that of Norway in Europe as the hub of CCUS on the North American east coast.

In summary, for Newfoundland and Labrador's long-term economic and environmental health, as well as that of the world, it is imperative that the province steeply begin and accelerate its planning, simulation, development, and implementation of CCUS.

## CONFLICT OF INTEREST

The author declares no conflict of interest.

## REFERENCES

- [1] IPCC. (2005). Carbon dioxide capture and storage. [Online]. Available: <https://www.ipcc.ch/report/carbon-dioxide-capture-and-storage/>
- [2] J. Skapin, (December 14, 2022). Energy NL CEO: Strong CCS potential in Newfoundland, Labrador. Daily Oil Bulletin. [Online]. Available: <https://www.dailyoilbulletin.com/article/2022/12/14/energy-nl-ceo-strong-ccs-potential-in-newfoundland/>
- [3] Government of Newfoundland and Labrador. (2017). Double oil and gas production in Newfoundland and Labrador – The way forward. [Online]. Available: <https://www.gov.nl.ca/thewayforward/action/double-oil-and-gas-production-in-newfoundland-and-labrador/>
- [4] J. Candela and D. Carlson, "The annual global carbon budget," *World Meteorological Organization Bulletin*, vol. 66, no. 1, 2017.
- [5] United Nations. (December 12, 2015). Paris agreement. [Online]. Available: [https://unfccc.int/sites/default/files/english\\_paris\\_agreement.pdf](https://unfccc.int/sites/default/files/english_paris_agreement.pdf)
- [6] A. Dalman, K. Dombrowski, D. Davis, *et al.*, "Offshore oil and gas infrastructure reuse for CCS: Opportunities and challenges in the U.S. Gulf of Mexico," in *Proc. the 16th Greenhouse Gas Control Technologies Conference*, 2022.
- [7] International Energy Agency. (July 11, 2023). Bioenergy with carbon capture and storage. [Online]. Available: <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/bioenergy-with-carbon-capture-and-storage>
- [8] 1PointFive. (July 25, 2022). DAC technology. [Online]. Available: <https://www.1pointfive.com/dac-technology>
- [9] 1PointFive. (May 31, 2023). 1PointFive holds groundbreaking for world's largest Direct Air Capture (DAC) plant. [Online]. Available: <https://www.1pointfive.com/1pointfive-holds-groundbreaking>
- [10] D. Sachde, K. Dombrowski, D. Davis, *et al.*, "Offshore oil and gas infrastructure reuse for CCS: Opportunities and challenges in the U.S. Gulf of Mexico," in *Proc. the 16th Greenhouse Gas Control Technologies Conference*, 2022.
- [11] Government of Canada. (April 14, 2023). Greenhouse gas emissions. [Online]. Available: <https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html>
- [12] Government of Canada. (August 24, 2023). Provincial and territorial energy profiles – Newfoundland and Labrador. [Online]. Available: <https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-newfoundland-labrador.html?=&wbdisable=true>
- [13] Equinor. (May 15, 2020). Historic investment decision for transport and storage of CO<sub>2</sub> – equinor.com. [Online]. Available: <https://www.equinor.com/news/archive/2020-05-northern-lights>
- [14] B. Lepic. (March 9, 2021). Norway approves plan for Northern Lights project. Offshore Energy. [Online]. Available: <https://www.offshore-energy.biz/norway-approves-plan-for-northern-lights-project/>
- [15] Northern Lights. About the longship project. [Online]. Available: <https://norlights.com/about-the-longship-project/>



- [16] Northern Lights. (March 4, 2021). What it takes to ship CO<sub>2</sub>. [Online]. Available: <https://norlights.com/news/what-it-takes-to-ship-co2/>
- [17] Natural Resources Canada, United States Department of Energy, Mexico Federal Electricity Commission, United States National Energy Technology Laboratory, and Mexico Secretariat of Energy. (2012). The North American Carbon Storage Atlas (1). Plataforma Mexicana de Captura y Almacenamiento de CO<sub>2</sub>. [Online]. Available: <https://meccs.org.mx/static/atlas/nacsa.pdf>
- [18] C. McGlade. (April 11, 2019). Can CO<sub>2</sub>-EOR really provide carbon-negative oil? – Analysis – IEA. International Energy Agency. [Online]. Available: <https://www.iea.org/commentaries/can-co2-eor-really-provide-carbon-negative-oil>
- [19] J. Simon. (May 21, 2023). A pipeline rupture in Satartia, Mississippi has lessons for future CO<sub>2</sub> projects. NPR. [Online]. Available: <https://www.npr.org/2023/05/21/1172679786/carbon-capture-carbon-dioxide-pipeline>
- [20] J. Brady and N. Banerjee. (June 9, 2021). Controversial Keystone XL pipeline is halted. NPR. [Online]. Available: <https://www.npr.org/2021/06/09/1004908006/developer-abandons-keystone-xl-pipeline-project-ending-decade-long-battle>
- [21] International Energy Agency. CO<sub>2</sub> transport and storage – Energy system – IEA. [Online]. Available: <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/co2-transport-and-storage>
- [22] Zero Emissions Platform. (March 2022). Network technology guidance for CO<sub>2</sub> transport by ship. [Online]. Available: <https://zeroemissionsplatform.eu/wp-content/uploads/ZEP-CCSA-Guidance-Note-for-CO2-transport-by-ship-March-2022.pdf>
- [23] L. G. H. van de Meer and F. Yavuz, “CO<sub>2</sub> storage capacity calculations for the Dutch subsurface,” *Energy Procedia*, vol. 1, no. 1, pp. 2615–2622, 2009.
- [24] M. J. Kaiser, “A review of exploration, development, and production cost offshore Newfoundland,” *Natural Resources Research*, vol. 30, no. 2, pp. 1253–1290, 2021.
- [25] M. Blunt. (December 2010). Carbon dioxide storage. In Grantham Institute for Climate Change Briefing paper (4). Imperial College London. [Online]. Available: <https://www.imperial.ac.uk/media/imperial-college/grantham-institute/publications/briefing-papers/Carbon-dioxide-storage---Grantham-BP-4.pdf>
- [26] MRST. (January 28, 2016). MRST-co2lab. SINTEF. [Online]. Available: <https://www.sintef.no/projectweb/mrst/modules/co2lab/>
- [27] Carbon Capture and Sequestration Technologies @ MIT. Sleipner fact sheet: Carbon dioxide capture and storage project. [Online]. Available: <https://sequestration.mit.edu/tools/projects/sleipner.html>
- [28] Norwegian Petroleum Directorate. (April 2014). CO<sub>2</sub> Atlas for the Norwegian Continental Shelf. [Online]. Available: <https://www.npd.no/en/whats-new/publications/co2-atlases/co2-atlas-for-the-norwegian-continental-shelf/>
- [29] Center for Climate and Energy Solutions. (October 2021). U.S. State Energy Financial Incentives for CCS. [Online]. Available: <https://www.c2es.org/document/energy-financial-incentives-for-ccs/>
- [30] Norwegian Petroleum. (July 4, 2023). Emissions to air – Norwegianpetroleum.no. Norskipetroleum.no. [Online]. Available: <https://www.norskipetroleum.no/en/environment-and-technology/emissions-to-air/>
- [31] A. Barreca. (March 24, 2023). Newfoundland and Labrador (NL) Budget 2023: New funding for economic growth and sustainability. Mentor Works. [Online]. Available: <https://www.mentorworks.ca/blog/government-funding/newfoundland-and-labrador-2023-budget/>
- [32] E. Preville. (April 6, 2023). The 2023 federal budget at a glance. HillNotes. [Online]. Available: <https://hillnotes.ca/2023/04/06/the-2023-federal-budget-at-a-glance/>
- [33] Congressional Budget Office. (February 15, 2023). The budget and economic outlook: 2023 to 2033. [Online]. Available: <https://www.cbo.gov/publication/58946>
- [34] IPCC. (2000). Special report on emission scenarios. [Online]. Available: <https://www.ipcc.ch/site/assets/uploads/2018/03/sres-en.pdf>

Copyright © 2024 by the authors. This is an open access article distributed under the Creative Commons Attribution License ([CC BY-NC-ND 4.0](https://creativecommons.org/licenses/by-nc-nd/4.0/)), which permits use, distribution and reproduction in any medium, provided that the article is properly cited, the use is non-commercial and no modifications or adaptations are made.