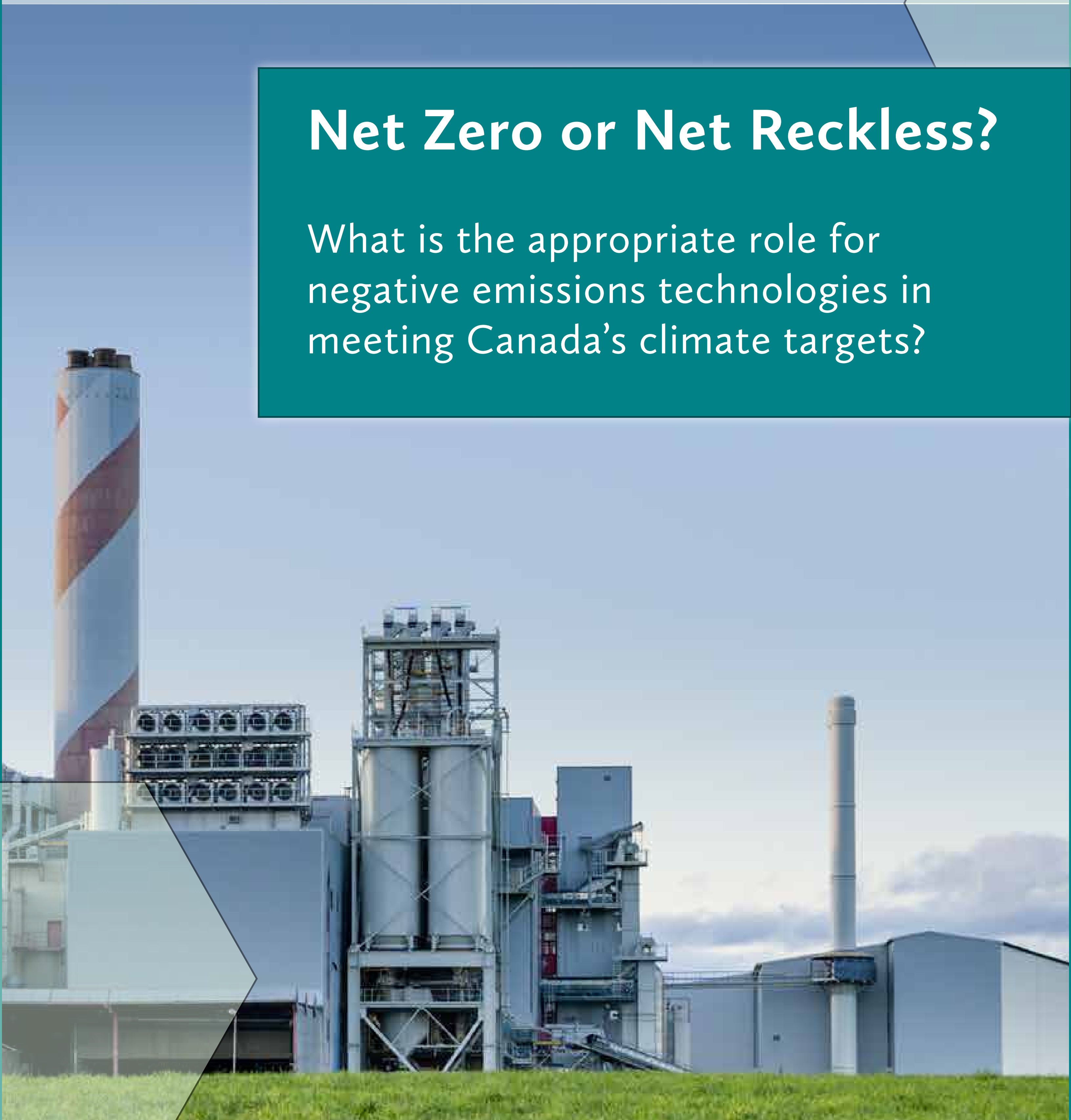

Net Zero or Net Reckless?

What is the appropriate role for negative emissions technologies in meeting Canada's climate targets?

WEST COAST
Environmental Law

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We would like to acknowledge that this report was created and conceived of on the unceded ancestral territories of the xʷməθkʷəy̓əm (Musqueam), Skwxwú7mesh (Squamish) & Səl̓ílwətaʔ (Tsleil-Waututh) and on the territory of the Lekwungen-speaking Peoples.

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West Coast Environmental Law harnesses the power of law to solve complex environmental challenges. We are transforming environmental decision-making and strengthening legal protection for the environment through collaborative legal strategies that bridge Indigenous and Canadian law. By putting the law in the hands of communities and creating legal risk for those who would harm our land, air and water, we are building the collective power to achieve a more just and sustainable future for all.

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Net Zero or *Net Reckless?*

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Executive Summary

The Intergovernmental Panel on Climate Change (IPCC) has stated that the world needs to achieve net-zero global emissions by 2050 in order to limit global temperature rise to 1.5 °C and avoid the worst impacts of climate change. Accordingly, like many jurisdictions around the world, Canada has set a net-zero emissions by 2050 target. This goal was given legal effect in 2021 in the Canadian Net-Zero Emissions Accountability Act (CNZEAA), which explains that "net zero" means "anthropogenic emissions of greenhouse gases into the atmosphere are balanced by anthropogenic removals of greenhouse gases from the atmosphere over a specified period."

The inclusion of anthropogenic removals in Canada's emissions target introduces a new dimension to Canadian climate law and policy, including the concept of "negative emissions." For the first time, Canada's climate target is not just about reducing the country's greenhouse gas emissions, but also about increasing "removals" to achieve a balance. CNZEAA does not define "anthropogenic removals," leaving Canada's Minister of Environment and Climate Change with considerable latitude to develop climate plans that include "negative emissions technologies" (NETs).

NETs are technologies that remove carbon dioxide (CO_2) from the atmosphere and permanently store it, resulting in the net removal of greenhouse gases from the atmosphere. NETs could potentially have a valuable role in restoring the health of the atmosphere and 'neutralizing' emissions associated with essential goods or services for which there is no realistic carbon-free substitute; however, given the risks and limitations of NETs, government regulation should take a cautious approach.

This paper examines the risks and limitations of industrial NETs, including Direct Air Capture (DAC) and Bioenergy with Carbon Capture and Storage (BECCS), explores key related questions, and concludes with recommendations to the Canadian government on the use of NETs in meeting climate targets. The recommendations may also be useful to other levels of government that have or are considering net-zero goals.

Are NETs necessary?

Virtually all of the IPCC's mitigation pathways to achieve 1.5 °C require the use of some "carbon dioxide removal" (CDR) to reach net zero (although CDR is needed less in pathways that have strong emphasis on energy efficiency and low demand). A large amount of the proposed CDR would be achieved through nature-based solutions (e.g. planting trees and changing agricultural practices), but most pathways also include a significant amount of anthropogenic removals, mainly from BECCS and to a much lesser extent DAC. Thus, even though there are many valid concerns regarding the use of NETs, it is hard to dismiss NETs entirely. Nevertheless, the IPCC is very clear that there are limits on how much and how quickly NETs should be used, and that NETs should be used specifically to neutralize emissions where no alternatives exist and to draw down the already too-high levels of CO_2 in the atmosphere. It is clear that governments must prioritize actual reductions in greenhouse gases, and the potential for removals should not be used as a basis for delaying emissions reductions.

The technologies

A literature review conducted by West Coast Environmental Law reveals that there are considerable challenges and constraints associated with NETs and CO_2 storage options.

Carbon Engineering pilot plant in Squamish, B.C. featuring Direct Air Capture technology (Photo credit: Pembina Institute, Flickr Creative Commons 2016)

DAC involves sucking vast amounts of ambient air through fans and filters to remove CO_2. DAC technology has yet to be demonstrated at a large scale, and is water- and energy-intensive and costly. Unless DAC is powered by renewables and the captured CO_2 is permanently stored, it will not achieve negative emissions.

BECCS involves growing biomass (such as wood or crops) or using waste organic matter that has sequestered carbon from the atmosphere and then burning it for energy, but using carbon capture technology to capture the CO_2, which is then permanently stored. While some plant waste may be available for burning with little environmental footprint, ramping up BECCS to the scale suggested in some 1.5 °C pathways would require a phenomenal amount of land, which could have serious repercussions for food security, biodiversity, land degradation, desertification, sustainable development, livelihoods, Indigenous rights and human rights.

Carbon Engineering pilot plant in Squamish, B.C. (Photo credit: Tracey Saxby

NETs are cousins to point source carbon capture and storage (CCS), which is often discussed in Canada as a tool to reduce emissions from fossil fuel economy. However, while CCS may help to reduce emissions from, for example, power plants or industrial plants, it does not remove CO_2 from the atmosphere – and does not even aim to achieve negative emissions. Furthermore, when the captured CO_2 is used to pump out even more oil in a process called enhanced oil recovery, which is frequently the case, it can actually result in increased emissions when the full life cycle is considered, since it increases fossil fuel production.

After the carbon is captured, it needs to be permanently stored. It is uncertain whether geological storage of CO_2 (i.e. injecting CO_2 deep underground) can be scaled up to the magnitude necessary, while other possible storage options, including deep ocean storage and carbon mineralization have also not been proven at scale. To be significant on a climate scale, the CO_2 transportation infrastructure required would be roughly equal in scale to today's oil and gas pipeline and marine transport networks, with similar risks of accidents and land rights challenges.

The available information about the risks and challenges of NETs supports the view that they should be used sparingly, and actual emissions reductions and shifts away from fossil fuel-based technologies should be prioritized.

What is the appropriate role for NETs in addressing global climate change?

Based on a review of reports by the Intergovernmental Panel on Climate Change, the International Energy Agency, and available academic literature, we have identified four key principles and a set of recommendations identifying how NETs should and should not be used to achieve a net-zero target.

PRINCIPLE #1

Because of the risks, limitations and uncertainties, use NETs only for atmospheric restoration (reversing historic emissions) and to compensate for emissions deemed essential and extremely difficult to decarbonize.

While there is a role for NETs, the IPCC and other scientific writers are clear that there are large risks with relying too much on these technologies and that urgent emissions reductions should be prioritized, with NETs only being relied upon in very limited circumstances. Even creating enough NETs for these limited purposes has been called "an atmospheric GHG restoration Manhattan Project." The literature review revealed there are huge uncertainties about whether and how quickly NETs could be brought up to a large scale, as well as significant economic, ecological, cultural and other costs associated with doing so (discussed in principle #3). There is no basis for using NETs to justify continued emissions from industries that can be decarbonized.

In addition, the literature reminds us that Canada has more capacity to reduce emissions and build NETs than many countries that have done less to contribute to the climate crisis. As a wealthy country, Canada must do its “fair share” and shoulder a greater burden of climate mitigation than the global average. To achieve the net zero by 2050 goal globally, wealthier countries, like Canada, should achieve net zero earlier than 2050, to allow less wealthy countries to achieve net zero a little later. Canada should build out NETs not to allow the country to emit more, but to compensate for its historical emissions.

Reliance on NETs in Canada’s climate plans for anything other than these limited purposes undermines the goals of the Canadian Net-Zero Emissions Accountability Act, creating huge risks that Canada will fail to meet its climate targets if it relies heavily on NETs.

Government targets and plans should specify what portion of the target, if any, will be achieved through NETs and they should only include NETs that are demonstrated to be currently scientifically feasible and scalable over the life of the plan. Canada’s climate laws and policies should be revised to prioritize actual greenhouse gas reductions and limit the use of NETs to essential processes where no alternatives exist.

Workers in Squamish, B.C. (Photo credit: Pembina Institute, Flickr Creative Commons 2016)

PRINCIPLE #2

Ensure that NETs result in actual and permanent removals of CO_2 from the global atmosphere, resulting in net-negative emissions.

Although NETs aim to remove CO_2 from the atmosphere, if they are not used appropriately, they can actually result in a net increase in emissions when the full life cycle is considered. To ensure that NETs live up to their name and truly achieve net negative emissions, it is vital that all emissions produced by the process are accounted for, including upstream and downstream emissions. It is also essential to have clear rules to ensure that CO_2 that has been removed is permanently stored and will not leak back into the atmosphere at some point in the future.

In addition, plans to achieve "net-zero" goals usually assume that one tonne of CO_2 added to the atmosphere equals one tonne removed. Scientists warn that this assumption is too simplistic. In actual fact, to reduce greenhouse gas concentrations in the atmosphere you likely have to remove more CO_2 than was added; the current best estimate of the true "balance" is 1.1 tonnes of CO_2 removals per tonne of CO_2 emitted.

Canada needs to enact clear rules and requirements to ensure that NETs remove carbon from the atmosphere permanently. Canada's Impact Assessment Act and other legislation and policies should ensure that emissions reductions are prioritized, and that NETs, if used at all, should be limited to processes which are necessary and for which no alternative exists. Where NETs are used, they should be demonstrated to be scalable over the life of the plan or project, based on what is currently scientifically feasible.

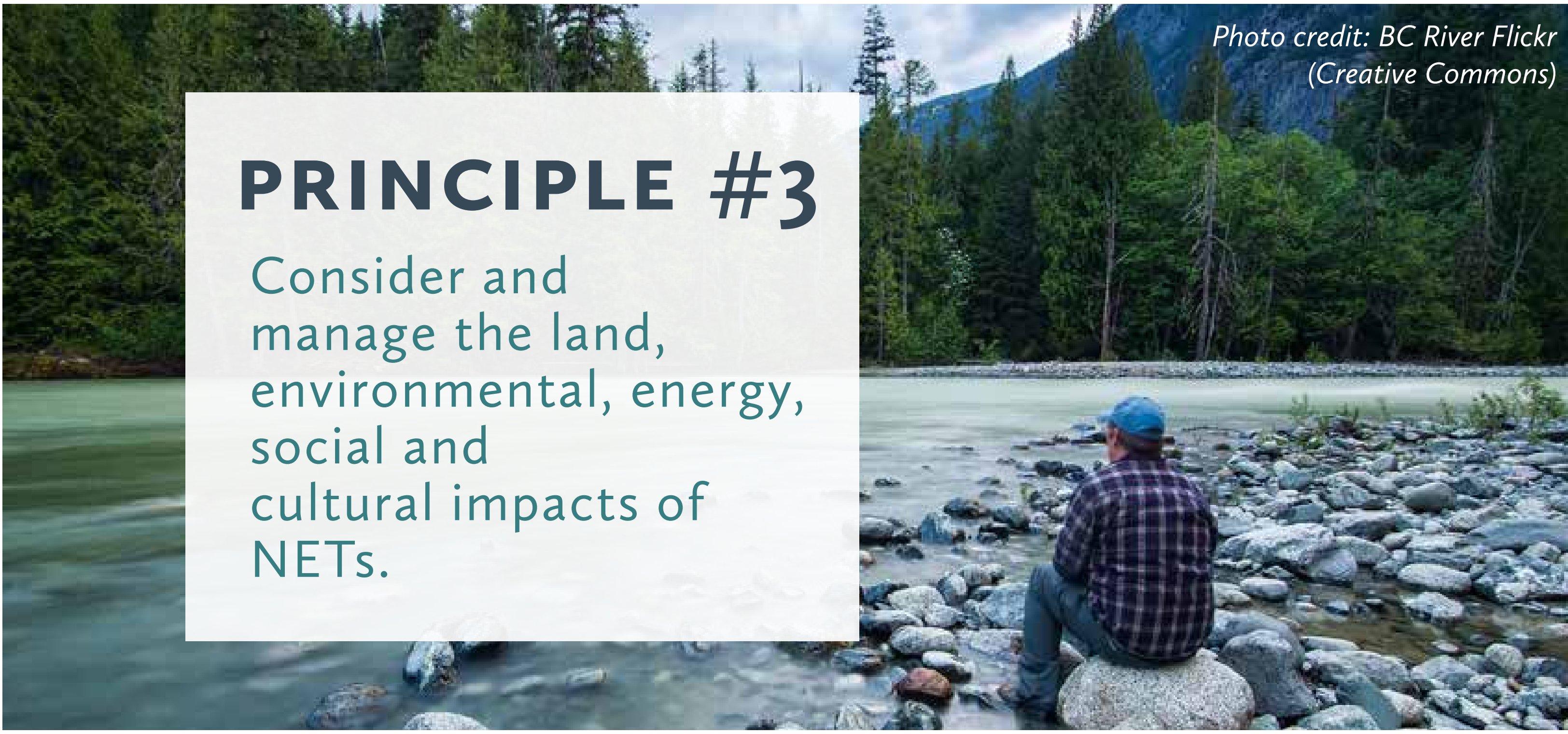

Photo credit: BC River Flickr (Creative Commons)

PRINCIPLE #3

Consider and manage the land, environmental, energy, social and cultural impacts of NETs.

Although the theoretical limit on how much CO_2 can be captured and stored is large, there are very real constraints on NETs related to energy, water, land and other resource use, and the speed with which the technologies can be deployed at scale. DAC is hugely energy- and water-intensive, while large-scale BECCS typically requires vast areas of land. Both technologies may, depending on where they are located relative to storage sites, require massive pipeline networks, with their own risks of leakage, explosions and environmental harm.

The challenges associated with ramping up NETs are exacerbated by the fact that addressing the climate crisis requires the rapid development of other infrastructure, both to reduce emissions and prepare for the impacts of climate change, and this is likely to compete with NETs for labour, materials and other resources.

Canada's climate laws, and associated regulations and policies, must fully assess and manage the broader impacts associated with the technologies. In particular, the UN Declaration on the Rights of Indigenous Peoples, especially the principles of self determination and Free, Prior and Informed Consent must be upheld for all NETs projects and related infrastructure.

PRINCIPLE #4

Ensure that polluters pay for the limited NETs that are needed.

A growing body of academic literature asks how we are going to create the financial incentives necessary to ramp up a barely existing industry at an unprecedented rate. Studies show that this will likely require government intervention. Several writers propose that carbon dioxide removal (CDR) be viewed as a "public service," analogous to waste disposal. A polluter pays approach in which public CDR is paid for through industry taxes and/or a carbon tax while industry is held to aggressive emissions reductions requirements could realize the potential of CDR to protect the public interest, but there is an opportunity cost as the money may be better used elsewhere.

There has been relatively little discussion of how NETs might be funded in Canada or who will ultimately own the infrastructure, but calls for large-scale public funding of private projects seem likely. However, from the point of view of ensuring that NETs are used where they are most needed, the government needs to retain ownership and/or control over the resulting technology or facilities.

(Photo credit: Jamesak Flickr (Creative Commons, 2022)

Conclusion

NETs bring with them a slew of risks and limitations, uncertainties and ethical questions, but given the importance of achieving a stable and safe climate, NETs cannot be dismissed altogether. It is extremely important that NETs are used sparingly – only to compensate for essential and extremely difficult to decarbonize emissions, and to draw down historical emissions – and that NETs are not used as an excuse to delay the drastic emissions reductions needed to reach net zero.

If and when NETs are used (for the limited purpose stated above), government regulation will be required to ensure that, among other things: full life-cycle assessments of NETs are conducted to assess their efficacy in reducing emissions; transparent monitoring, reporting and verification is in place to provide accurate accounting of carbon sequestration; careful consideration of land, energy and water use is undertaken to inform siting and avoid environmental and social impacts; and that polluters pay for the costs of NETs.

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I. Introduction: Canada's net-zero target – Opening the door to negative emissions technologies?

In 2019, the re-elected federal government confirmed its election promise to work to reduce Canada's greenhouse gas emissions to "net zero" by 2050 – a new climate commitment that treats climate action like a balance sheet, and by extension, introduces the concept of "negative emissions" to Canadian legal discourse.

The net zero by 2050 goal was given legal effect in 2021 in the new Canadian Net-Zero Emissions Accountability Act (CNZEAA)[1] which defines net zero as follows:

> anthropogenic emissions of greenhouse gases into the atmosphere are balanced by anthropogenic removals of greenhouse gases from the atmosphere over a specified period.[2]

For the first time, Canada's climate target is not just about reducing the country's greenhouse gas emissions, but also about increasing greenhouse gas "removals" to achieve a balance. This inclusion of "anthropogenic removals" in a target introduces a new dimension and new questions into Canadian climate law and policy. For example, to what extent will the targets be achieved based on emissions reductions, and to what extent will Canada rely on new technologies, known as Negative Emissions Technologies (NETs), to remove greenhouse gases from the atmosphere? And what removals are considered anthropogenic? CNZEAA gives little direction, leaving Canada's Minister of Environment and Climate Change with considerable latitude to set targets and plans that include NETs.

While a net-zero target can be achieved either by reducing emissions, increasing removals, or some combination thereof, the actual combination of emissions reductions versus removals makes a huge difference in terms of what our country needs to do to achieve the goal, the consequent costs, risks and impacts, and ultimately whether it gets us to net zero by 2050.

Shortly after the CNZEAA was introduced in Parliament, the Canadian Institute for Climate Choices released a report, Canada's Net Zero Future[3], which modelled different possible "pathways" that might allow Canada to achieve net zero by 2050. The CCIC Report illustrates the impact that technological solutions to remove carbon dioxide (CO_2) from the atmosphere could have on government plans to achieve a net-zero target. Most of the pathways to net zero require dramatic decreases in the burning of fossil fuels; however, the pathways that assume that NETs become widely and cheaply available enable the...

> ...continued (or even growing) use of fossil fuels throughout the economy. Emissions-intensive sectors whose mitigation costs would be high could continue to use their existing production processes, offsetting their emissions with negative emissions that would occur elsewhere instead of reducing or capturing them at source.[4]

It is easy to see, then, why the CNZEAA target of net zero by 2050 was applauded by the Canadian Association of Petroleum Producers and several oil and gas companies:

> Any pathway to net zero includes the efficient use of oil and natural gas. Considerable investment in technology and innovation at scale will be needed, including negative emissions technologies...[5]

In theory, a net-zero target could be achieved not by cutting back on fossil fuel pollution, but rather, by removing huge quantities of CO_2 from the atmosphere each year to cancel out continued greenhouse gas pollution. Such an approach, the Canadian Association of Petroleum Producers hopes, would allow the continued profitability of the industrial players that it represents.

The Canadian Institute for Climate Choices Report (and as we shall see, many international reports) cautions that NETs (and their associated infrastructure) are unproven at the huge scales required to achieve net zero, and that there are massive risks to Canada and the world in relying on technologies that might not work as hoped. The Canadian Institute for Climate Choices describes this future as "a seductive but risky possibility,"[6] emphasizing that Canadian oil and gas production can only be consistent with net zero if "a very specific (and uncertain) combination of outcomes and conditions comes to pass – many of which are highly uncertain, not to mention outside of Canada's control."[7]

A path to net zero that relies upon steep emissions reductions in the present decade with a small amount of carbon dioxide removal (CDR) will look entirely different than a path with only modest emissions reductions over the next couple of decades, accompanied by a dramatic ramp-up of NETs. The latter scenario would result in many times more emissions and put all of the country's eggs into one technological/industrial basket.

Figure 1, Two Paths to Net Zero, compares a path that has deep emissions reductions supplemented by a modest amount of CDR (Path 1) with a path that delays emissions reductions and must rely on a much larger amount of CDR, ramping up in decades to come to achieve net zero by 2050 (Path 2). For each path the solid line indicates emissions reductions, while the dotted line shows CDR including NETs. The amount of CDR required is shown by the shaded area. The unshaded area between paths 1 and 2 represents the excess emissions that would result from taking path Net zero, then, is an imprecise goal because it gives little guidance on how to achieve it. The path to net zero can look entirely different to reasonable people, depending on each person's assessment of how realistic, reliable, affordable, scalable and/or desirable NETs are.

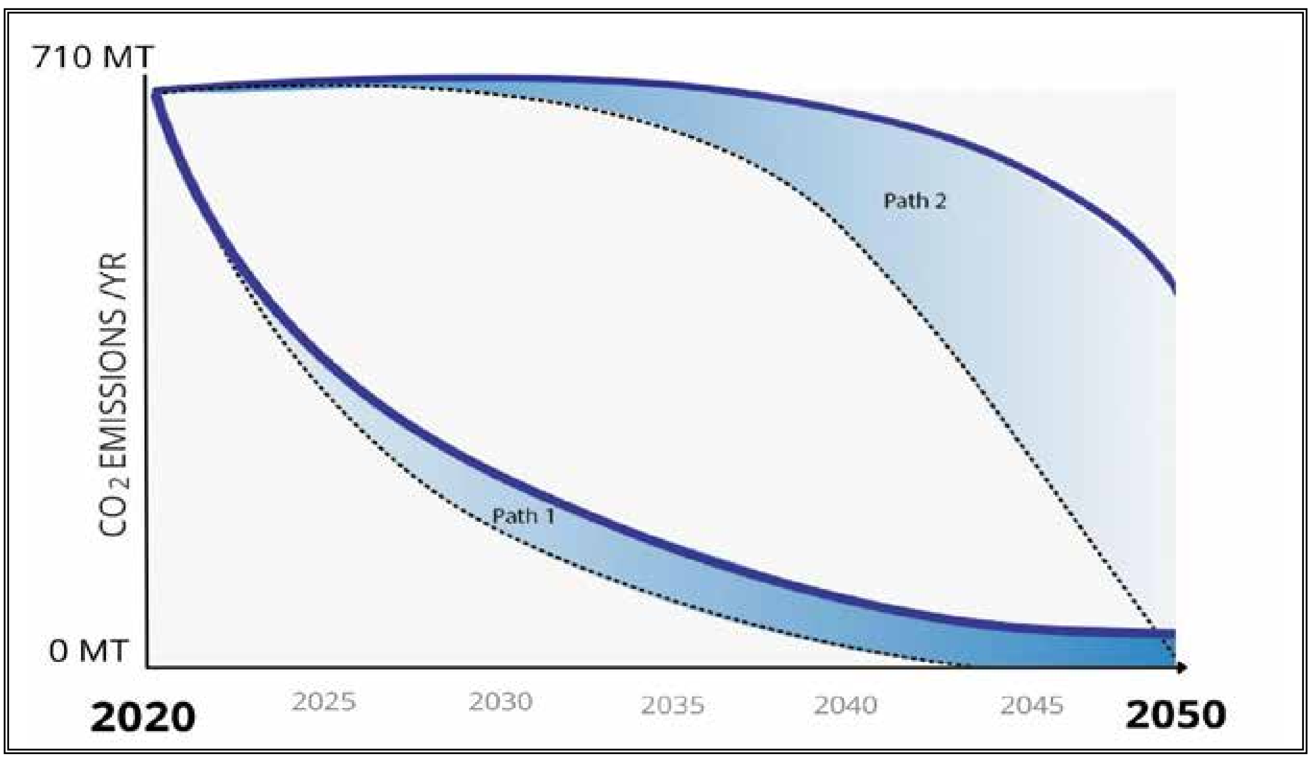


Figure 1: Two pathways to Net Zero (WCEL)

As we will see, most international projections of pathways to net zero include at least some NETs. These technologies could play a valuable role in restoring the health of the atmosphere and 'neutralizing' emissions associated with essential goods or services for which there is no realistic carbon-free substitute.

At the same time, however, it is important not to be unrealistically optimistic about these technologies, expecting engineering and miraculous breakthroughs to roll out just in time to save the world. Even if the technologies are viable, there are likely to be real limits on their use and how quickly they can be developed. Given the risks and limitations of NETs, governments should take a cautious approach and regulate to ensure that NETs are deployed in ways that will do the most good and not at the expense of actually reducing emissions.

Part II of this report considers whether NETs are necessary at all, and reviews some of the academic literature on the technologies to assess their risks and limitations.

Part III looks at the appropriate role for NETs in addressing global climate change, and explores a number of important questions that must be considered.

Part IV examines what we know about Canada's plans to use NETs, and makes recommendations for governance of NETs in Canada, including how they should relate to the country's net-zero emissions target.

Part V summarizes our conclusions.

II. Are NETs necessary, and what are the technology options and limitations?

What do we mean by Negative Emissions Technologies (NETs)? When we refer to either "negative emissions" or "carbon dioxide removal" we are referring to intentional efforts to remove CO_2 from the atmosphere (see the box on page 6 for more of a discussion about the differences between these two terms). Carbon Dioxide Removal (CDR) can refer to devices and hardware, or practices and behaviours, that achieve negative emissions, such as afforestation, soil carbon sequestration, solar radiation management, Direct Air Capture and Storage (DACS) and Bioenergy Carbon Capture and Storage (BECCS), among others. Our report focuses specifically on the types of CDR that use industrial technologies to capture the CO_2 and store it, such as DACS and BECCS, and we will refer to these technologies as Negative Emissions Technologies (NETs). We focus only on CO_2 removal in this report, although there are technologies for removing other greenhouse gases as well.

DACS and BECCS are broadly related to a wide range of technologies known as Carbon Capture and Storage (CCS), or sometimes Carbon Capture Utilization and Storage. CCS as it is currently used in Canada is not a negative emissions technology, but rather focuses on capturing CO_2 emissions that would otherwise enter the atmosphere from a large emissions source, such as a power plant. Moreover, very little of the captured CO_2 is permanently stored, since there are few economic incentives for industry to do so. Despite these realities, industry and some politicians suggest that CCS could allow the oil and gas industry to address its emissions while still increasing production, regardless of the fact that CCS can only reduce, and not eliminate, emissions, and that it cannot address the emissions that occur when the produced oil and gas is burnt.

While some of the recommendations and findings of this report will be relevant to CCS, our focus is on NETs, where CO_2 is captured out of the air and permanently stored. CCS is discussed only where its more extensive history provides lessons about challenges that NETs might face and/or how government might regulate it.

Carbon Dioxide Removal, Negative Emissions Technologies and Nature-based Solutions

Carbon Dioxide Removal (CDR) is used by the Intergovernmental Panel on Climate Change and much of the academic literature as a broad term that refers to human-caused processes that intentionally draw CO_2 out of the atmosphere. Negative Emissions Technologies (or NETs) refers to technologies that result in the net removal of greenhouse gases from the atmosphere. Sometimes the term is used interchangeably with CDR, but it can also refer specifically to industrial and engineered processes that remove CO_2. This latter meaning of NETs is the focus of this report, and in general we use the term NETs except where we intend to refer to both industrial technologies and other approaches to CO_2 removal (in which case we use the term CDR).

Although not covered in this report, CDR also includes “nature-based solutions” that enhance existing natural processes to increase the removal of carbon from the atmosphere (e.g. by increasing CO_2 uptake by trees, soil, or other ‘carbon sinks’). Nature-based solutions for climate change entail protecting, restoring and managing natural ecosystems to aid in mitigating the effects of anthropogenic climate change through carbon sequestration and avoided greenhouse gas emissions.[8] This can involve initiatives like the mass-planting of trees and the conservation of carbon-storing ecosystems like wetlands and mangrove forests. Some researchers believe that natural climate solutions have the capacity to contribute significantly to the emissions reductions necessary to keep global average temperature rise under 2°C,[9] reducing the need for NETs.

Nature-based strategies can be enticing because they may address more than one environmental issue at the same time; in addition to sequestering carbon, nature-based solutions can, for example, protect biodiversity or make shoreline habitats more resilient to sea level rise and storm surges. However, the capacity of nature-based solutions is limited. Uptake and storage from trees, grasslands, wetlands, estuaries and other ecosystems are already relied on to remove CO_2 that has already been released into the atmosphere, both from anthropogenic emissions and as part of the natural carbon cycle. Therefore, the management and quantification of nature-based climate solutions can be complicated.[10]

Moreover, nature-based solutions typically store CO_2 in biological systems, which usually are not nearly as permanent as geological systems, particularly given the human-caused stresses facing these ecosystems. Forests and other natural systems may burn (especially in a world affected by climate change) or be cut, releasing the sequestered carbon. In contrast, burning fossil fuels releases carbon that has been stored for millions of years, and therefore, to compensate for fossil fuel emissions, we should be sequestering carbon for millennia.

Finally, it is of utmost importance that nature-based solutions are implemented with the full engagement and consent of Indigenous peoples and local communities in a way that respects their cultural and ecological rights.

2.1 Are NETs necessary?

When the world's governments committed in the 1992 United Nations Framework Convention on Climate Change to reduce greenhouse gas emissions to avoid dangerous climate change, it was accepted that this meant reducing emissions spewing from fossil fuel production and combustion and other sources. The world has so far failed to achieve that goal and global greenhouse gas concentrations have continued to rise.

In 2015 the world's governments pledged in the Paris Agreement to keep global temperature rise to "well below 2 °C above pre-industrial levels" and to work to keep that temperature rise to 1.5 °C or less.[11] The Parties to the Paris Agreement asked the Intergovernmental Panel on Climate Change (IPCC), the Nobel Prize winning network of scientists that advises governments on climate science, what the difference in impact would be between a 1.5 °C and 2 °C global increase in temperature.

Climate treaties and the international use of NETs

The focus of this report is on the use of NETs in achieving Canada's greenhouse gas reduction targets. However, a CO_2 removal that occurs in Canada will not necessarily be counted towards Canada's emissions targets.

For many years, international climate negotiators have discussed the possibility of transferring credit between countries for steps taken to reduce or remove greenhouse gases. Some environmental organizations and Indigenous voices have expressed concern that international transfers, particularly in a market, may undermine climate action, result in double-counting of emissions reductions, or have other unintended consequences.

The Conservation Through Reconciliation Partnership, for example, warns that:

> Serious negative consequences can follow when market-driven approaches to climate change solutions are designed with only carbon sequestration in mind, and when they are not led by Indigenous Nations or created within an Ethical Space. For example, there may be reduced access to traditional territories, infringement on Indigenous rights and reduction in biodiversity.[12]

While the Kyoto Protocol and other earlier international climate agreements set the stage, the rules for these transfers were finalized at the 2021 climate talks in Glasgow.[13] While not explicitly referring to NETs, it is possible that the rules could be used to allow Canadian companies to remove carbon from the atmosphere, and then, with the permission of the Canadian government, sell the removed CO_2 (the "mitigation outcome") to another country or companies in another country. These CO_2 removals would then no longer be counted towards Canada achieving its target, but instead towards the targets of the other country.

The IPCC's 2019 Special Report: Global Warming of 1.5 °C (the "1.5 °C Report") found that the differences were stark, with substantial impacts in a 2 °C scenario that could be avoided if global temperature rise was limited to 1.5 °C or less. Importantly, the IPCC also showed that there are pathways to keep global temperature rise to 1.5 °C, but most require reaching net-zero CO_2 emissions globally around 2050 and using CDR to help achieve that goal:

> All analysed pathways limiting warming to 1.5 °C **with no or limited overshoot use CDR** to some extent to neutralize emissions **from sources for which no mitigation measures have been identified and, in most cases, also to achieve net negative emissions to return global warming to 1.5 °C** following a peak (high confidence).[14] [*Emphasis added*]

The IPCC 1.5 °C Report shows numerous possible pathways to stabilizing the global atmosphere at levels consistent with a 1.5 °C rise in global temperatures, and each of these pathways use varying amounts of CDR. According to the report, a large amount of the proposed CDR would be achieved through nature-based solutions (e.g. planting trees, changing agricultural practices); however, most pathways also include a significant amount of NETs, mainly from Bioenergy with Carbon Capture and Storage (BECCS), and to a much lesser extent, Direct Air Capture (DAC). Yet the 1.5 °C Report also repeatedly cautions that these technologies are not proven at the scale needed. Many of the pathways require NETs (primarily BECCS) in the range of 3 to 7 gigatonnes of CO_2 (GtCO2) per year by 2050, in addition to a massive-scale use of nature-based solutions. Even with that level of NETs, global industrial and fossil fuel emissions must drop from 36.81 GtCO2/yr in 2019[15] to 10.3-13.1 GtCO2/yr by 2050[16].

There are limits, however, to the IPCC's modelling. One recent paper noted that all of the 222 scenarios considered in the 1.5 °C Report presupposed continued economic growth. The paper suggested that responding to climate change might instead require the world to forego economic growth in favour of rapidly reducing greenhouse gas emissions and getting better value from existing economic assets. The paper examined some alternative "degrowth" scenarios, in which emissions reductions were prioritized and economic growth was not assumed. These scenarios still required some CDR, but at rates far lower than the 1.5 °C Report scenarios.[17]

While intriguing, it is interesting to note that both the IPCC and these degrowth scenarios do require at least some use of CDR to limit global warming to 1.5 °C, and the IPCC modelling remains the most generally accepted roadmap to achieving the 1.5 °C goal.

Many environmental organizations have been deeply skeptical of NETs, fearing that they will turn out to be an expensive distraction from more achievable emissions reductions. Similarly, some Indigenous voices have cautioned that:

> CDR is not an effective, feasible, or equitable tool for achieving net-zero emissions. Reliance on CDR to achieve net-zero will replace absolute GHG emissions reductions and will result in Canada failing to address its emissions - leaving Indigenous communities to continue to bear the brunt of climate change impacts.[18]

Nonetheless, given the widely-accepted need to achieve 1.5 °C, it is difficult to entirely dismiss NETs given their importance in the IPCC's modelling of what is required to achieve 1.5 °C.

Yet the IPCC's 1.5°C Report is also very clear that the NETs are to be used for specific purposes – neutralizing emissions where no alternatives exist, and drawing down CO_2 already in the atmosphere.

"Where no alternatives exist" is a crucial point. For society to function, there might be some emission sources that are considered absolutely essential and extremely difficult to decarbonize. For example, while changes in agricultural practices and food consumption can dramatically decrease greenhouse emissions from the agricultural sector, global food security is essential and there are likely some emissions from farming and other food production that will be extremely challenging to eliminate.

One can debate precisely which industrial and other emissions sources are absolutely essential and cannot be decarbonized, but it is clear that many industries that are the source of massive emissions and for which alternatives exist – such as the energy and power generation sectors – are using the promise of NETs as a reason to avoid transitioning to low-carbon alternatives.

NETs must not be used as an excuse to continue emitting greenhouse gases where emissions reductions may simply be costly. Such technologies should only be used to compensate for essential and extremely difficult to decarbonize emissions. Those sectors, industries, industrial processes or other functions that are hard to decarbonize but not essential may eventually need to be eliminated altogether if their emissions cannot be reduced to zero.

The 1.5 °C Report also offers several cautions on delaying emissions reductions and over-relying on CDR:

> The longer the delay in reducing CO_2 emissions towards zero, the larger the likelihood of exceeding 1.5°C, and the heavier the implied reliance on net negative emissions after mid-century to return warming to 1.5°C (high confidence). ... CDR deployed at scale is unproven, and reliance on such technology is a major risk in the ability to limit warming to 1.5°C. CDR is needed less in pathways with particularly strong emphasis on energy efficiency and low demand.[19]

Moreover, the IPCC warns that even if technologically viable, there are limits to the "speed, scale and societal acceptability" of dramatic increases in CDR deployment.

Very importantly, the 1.5 °C Report is clear that:

(a) The planet as a whole needs to achieve net-zero greenhouse gas emissions by 2050;

(b) Some level of CDR is necessary to achieve global commitments to limit global warming well below 2°C and to keep the effects of climate change to somewhat manageable levels;

(c) There are limits on the realistic amount of CDR that can occur in the necessary time frame;

(d) CDR should be used to "neutralize" emissions from sectors that are necessary but for which mitigation options are insufficient, and to restore the global atmosphere;

(e) Dramatic and early reductions of actual emissions would decrease the need for extensive CDR; and

(f) CDR should not be used as a reason to avoid or delay emissions reductions.

The IPCC is not the only prominent international body modelling the emissions reductions and removals needed to limit global warming to 1.5 °C. The 2021 International Energy Agency (IEA) Report, Net Zero by 2050: A Roadmap for the Global Energy Sector, predicted that with massive effort, BECCS and DAC could capture a total of 2.4 $GtCO_2$/yr, of which 1.9 $GtCO_2$/yr would be permanently stored (and the rest used for carbon-neutral fuel).[20] Similar to the IPCC, the IEA is clear that these emissions removals are primarily required to "offset" greenhouse emissions from "sectors where technology options are scarce."[21]

In sum, to achieve net zero by 2050, it is apparent that some emissions removals will likely be necessary. However, as cautioned by the IPCC, and as explained in the following sections of this report, there are significant risks and limitations associated with CDR, and it is imperative that society not depend upon CDR too heavily.

2.2 The technologies

What are the specific Negative Emissions Technologies available to address the need for emissions removals identified by the IPCC's 1.5 °C Report? How realistic is it to argue that they can be built out to the scale required identified in the IPCC report or larger? What are the risks associated with doing so?

The next several pages provide an overview of industrial NETs and CO_2 *storage options, including the risks and limitations of each, based on a review of the available scientific literature. First, we look at the technologies DAC and BECCS. We also touch on point source carbon capture, which, as noted above, is not technically a NET; however, the technology is closely related to industrial NETs and has therefore been included. We then examine issues related to transporting* CO_2 *from the capture site to the storage site, and the possible storage methods for permanently storing captured* CO_2*.*

LEGEND

PERMANENCE
Will the CO_2 be stored permanently?

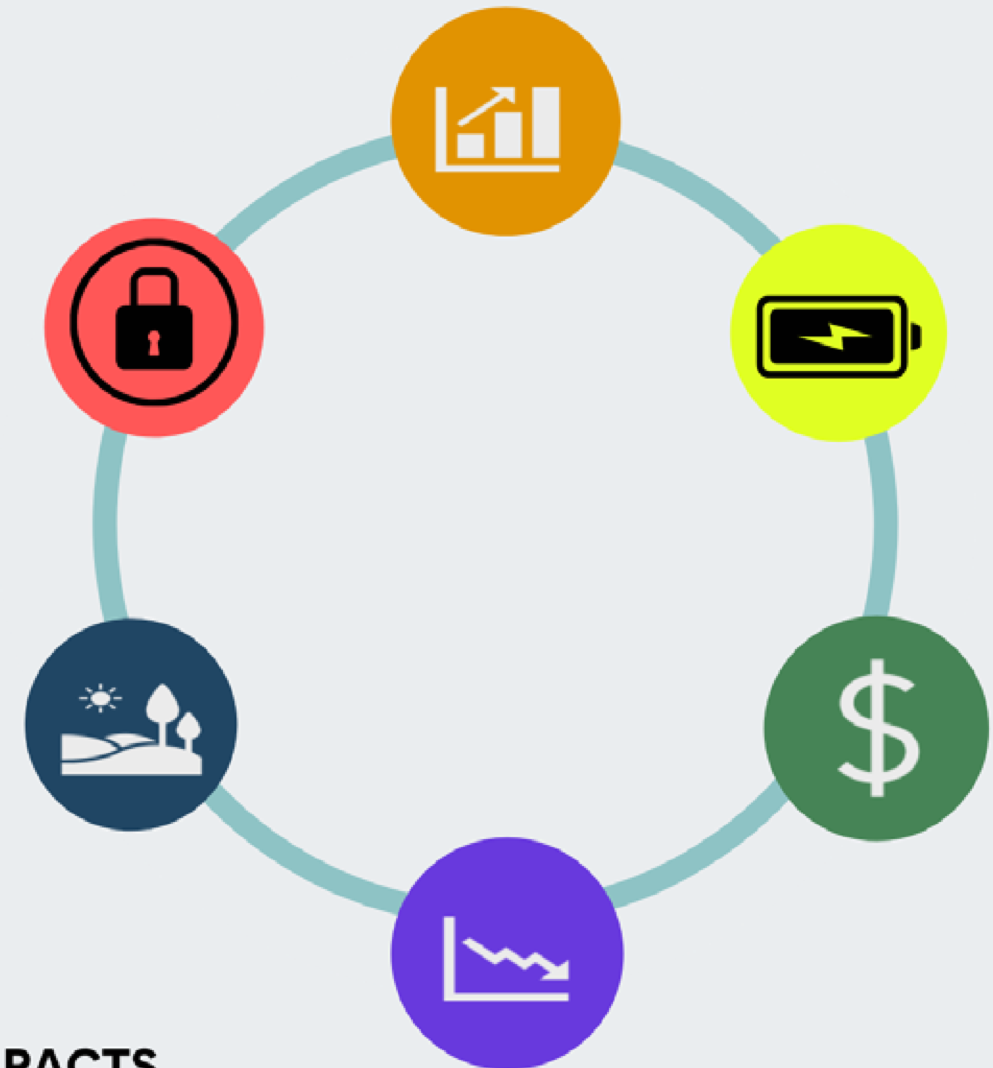
SCALABILITY
Can the technologies be scaled up quickly enough, and to the extent necessary to be consistent with a 1.5C pathway?

ENERGY NEEDS
How much energy is required to operate the technology?

COST
Is this technology a cost-effective way to reduce atmospheric CO_2?

GHG REMOVAL POTENTIAL
How much carbon could be sequestered each year by this technology?

ENVIRONMENTAL & SOCIAL IMPACTS
What are the land and water requirements associated with the technologies and the related impacts for society?



CARBON CAPTURE TECHNOLOGIES

POINT SOURCE CARBON CAPTURE & STORAGE **(CCS/CCU/CCUS)**

DIRECT AIR CAPTURE **(DAC)**

BIOENERGY WITH CARBON CAPTURE **(BECCS)**

CCS

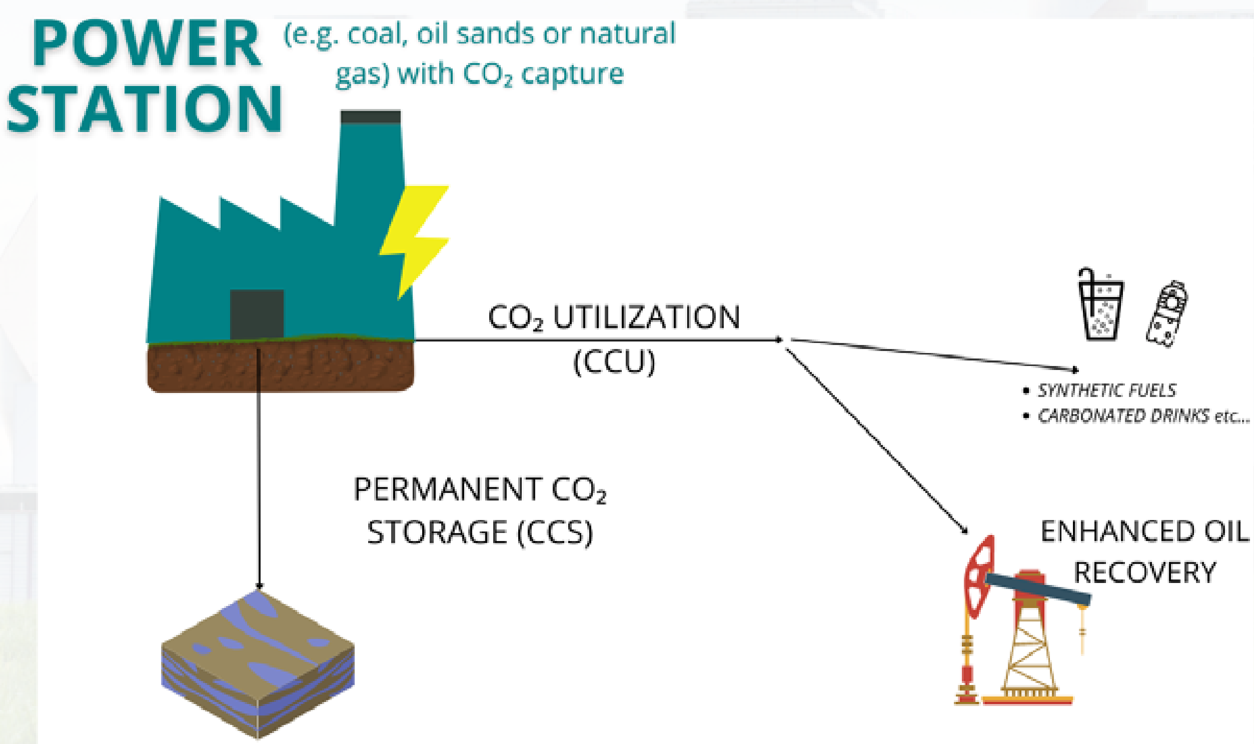
POINT SOURCE CARBON CAPTURE & STORAGE

CO_2 can be separated and captured from point sources, like the flue gases of power and industrial plants. The three principal technologies are: post-combustion capture;[22] pre-combustion capture; and oxyfuel combustion.

CCS can help to lower CO_2 emissions in sectors where other decarbonization technologies are limited, such as cement production.

However, point source carbon capture and storage does not remove CO_2 from the atmosphere, and therefore although it can lower flue gas emissions it is <u>not</u> a "negative emissions technology".

Furthermore, when the captured CO_2 is used for enhanced oil recovery, it can actually result in increased emissions when the full life cycle is considered since it increases fossil fuel production.



Theoretically CCS has the potential to reduce emissions by 90% but in practice capture rates are much lower.

Plants that use CCS require 15-25% more energy than they would without the CCS.[23]

There are ~21 Carbon Capture Use and Storage (CCUS) facilities with a combined capacity of 40 $MtCO_2$/year. Most of these facilities sell the CO_2 for enhanced oil recovery rather than storing it permanently.[24]

According to the IEA, if all planned CCUS projects are built, the capacity would reach 130 $MtCO_2$/year globally.[25]

RISKS

CCS

POINT SOURCE CARBON CAPTURE & STORAGE

PERMANENCE

The permanence depends on whether the captured CO_2 is stored or used. If permanently stored in geological formations, there is only a small chance of leakage. If used for enhanced oil recovery, there will be an increase in overall CO_2 emissions.

ENERGY NEEDS

Point source carbon capture technologies are energy intensive. Estimates range from 0.2-0.5 MWh per ton of CO_2 removed. Plants that use CCS require 15-25% more energy than they would without the CCS. [26]

GHG REMOVAL POTENTIAL

Point source carbon capture technologies are not designed to remove carbon from the atmosphere. They can prevent some CO_2 from entering the atmosphere, but only if the captured CO_2 is permanently stored. Currently most of the captured CO_2 is used for enhanced oil recovery, therefore facilitating the fossil fuel continuation and expansion.

If all planned CCUS projects are built, the capacity would reach 130 $MtCO_2$/year, or ~0.3% of current emission levels.

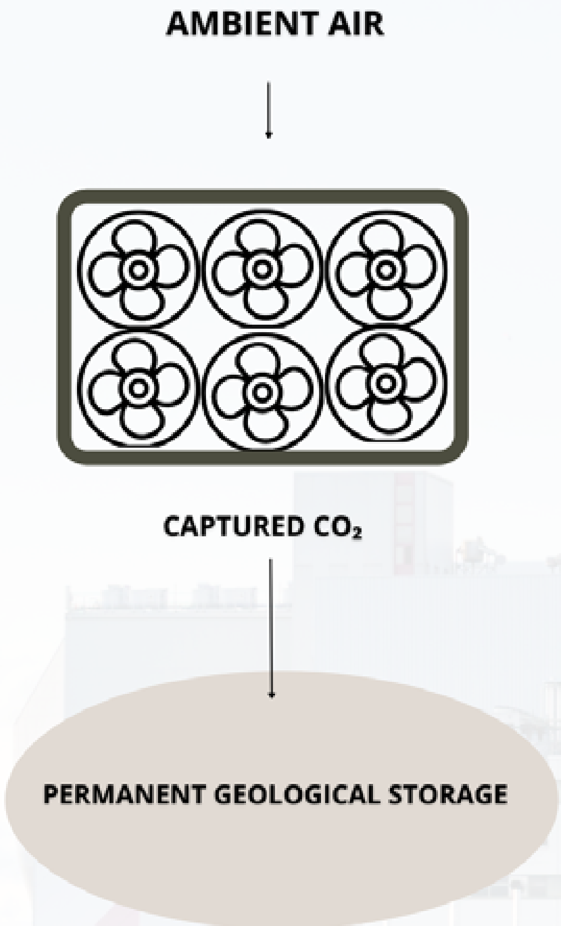
OTHER ENVIRO / SOCIAL IMPACTS

Because CCS requires 15-25% more energy/fuel, there are upstream and downstream impacts related to increased fuel production (e.g. non CO_2 pollutants).

Carbon capture systems can be installed on existing power plants and industrial factories so do not require a lot of land; however the transport of captured CO_2 to storage sites may require extensive pipeline construction, unless the CO_2 storage site is located very close to the capture point.

DAC

DIRECT AIR CAPTURE



DAC technology pulls in ambient air and, through a series of chemical reactions, extracts the CO_2 while returning the rest of the air to the environment. There are two main types of DAC systems, using either liquid solvents or solid sorbents.

Fifteen DAC plants are operational in Europe, the US and Canada (including a demonstration plant in Squamish, BC); however, most of these plants are small and sell the captured CO_2 for use – for carbonating drinks or for enhanced oil recovery, for example – rather than sequestering the carbon for permanent storage. In total, the 15 plants capture approximately 9 $MtCO_2$/year globally.[27]

The world's biggest DAC plant opened in Iceland in 2021. It pumps just 0.004 Mt of captured CO_2 underground per year.[28]

The first large-scale DAC plant is being built in the US and is expected to become operational by 2023. It will capture up to 1 $MtCO_2$/year for use in enhanced oil recovery.[29]

Due to the very low concentration of CO_2 in ambient air (compared to more concentrated CO_2 sources such as flue gas), DAC technology is considerably more energy intensive and costly than point source carbon capture.

The two main DAC systems have very different temperature and therefore energy requirements. Liquid solvent systems require 900°C to release captured CO_2, whereas solid sorbent systems require 80-120°C.[30]

Water usage depends on the system type, as well as the ambient temperature and humidity. Siting DAC in cooler and humid areas will minimize water use. For a liquid solvent DAC system, capturing 1 tonne of CO_2 requires between 1 and 7 tonnes of water. Solid sorbent systems vary widely in terms of water use.[31]

According to one study, DAC at scale would require a massive deployment and "major refocusing of the manufacturing and chemical industries for sorbent production, and a large need for electricity and heat."[32]

RISKS

DAC
DIRECT AIR CAPTURE

PERMANENCE

Like other carbon capture technologies, the permanence depends on what happens to the CO_2 after it is captured. It is currently common for the captured CO_2 to be used (not stored) in part to defray the high costs. The consequence is that the CO_2 is not permanently locked away.

To be a negative emissions technology, the CO_2 must be permanently stored.

ENERGY NEEDS

Considerable energy is required for DAC systems. The minimum energy requirement just for the chemical reactions is 1.8 GJ per ton of CO_2 removed

When processing and transportation etc. are accounted for, this could jump to 45 GJ per ton of energy required.[34]

One study estimated that it would require all of the wind and solar energy generated in the U.S. in 2018 to power enough DAC to capture just 0.1 $GtCO_2$[35]

SCALABILITY

There are very few examples of operational DAC – and so far all are small-scale.

Given the very high costs and extensive energy and water requirements, as well as its low stage of development, there are many uncertainties about whether DAC can be scaled-up quickly enough to help achieve climate targets.

COST

More than 50x the cost per ton of CO_2 removed compared to most natural climate solutions and also more expensive than flue gas capture.

The reported cost of DAC systems range between $100 - $1000 ton of CO_2 captured.[33]

OTHER ENVIRO/ SOCIAL IMPACTS

The land area needed for large-scale DAC deployment depends on the type of DAC system and the energy resource powering it.

Capturing a billion tonnes of CO_2 would require between 400 to 24,700 km2.[36]

Water needs can be huge depending on system type and ambient temperature and humidity.

BIOENERGY WITH CARBON CAPTURE AND STORAGE

BECCS

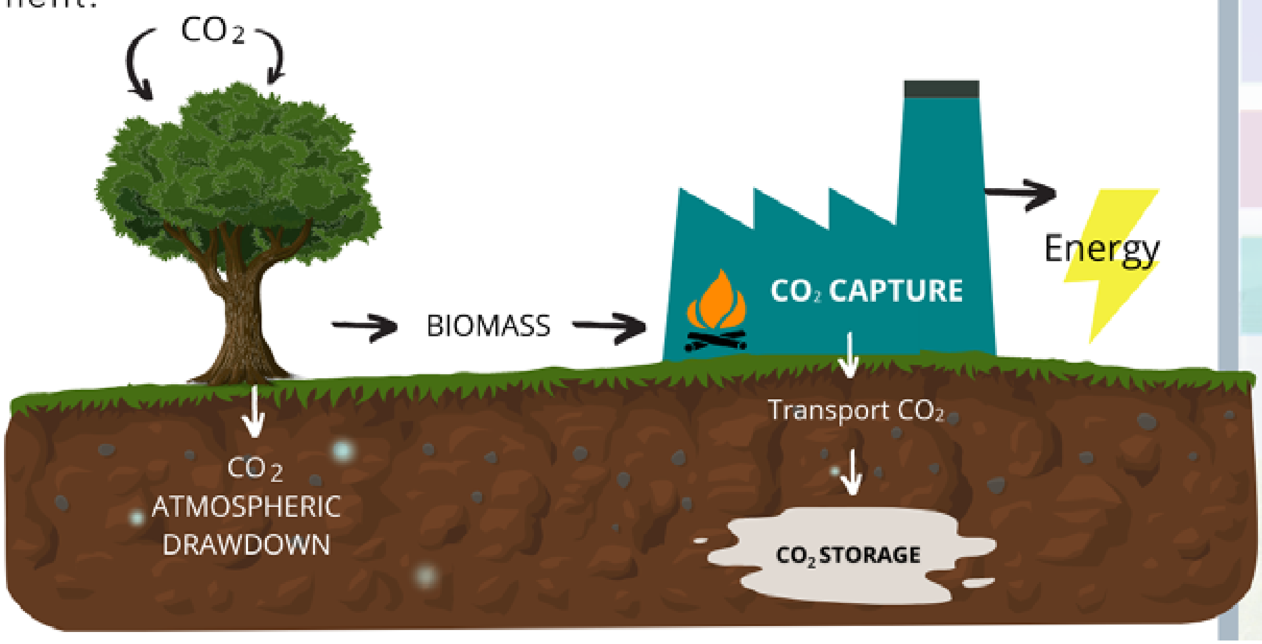
Bioenergy with carbon capture and storage (BECCS) is a combination of two technologies: large-scale biomass energy, and carbon capture and storage. In a BECCS system, CO_2 is removed from the atmosphere through photosynthesis as crops and trees grow. The plant material (biomass) is harvested and transported to a facility where it is burned and converted into energy. CO_2 is not re-released when it is burned. Instead, it is captured and stored.

Bioenergy is already widely used for energy generation; however, BECCS (i.e. with capture and storage) has struggled to move beyond demonstration projects.

BECCS requires enormous amounts of land, water and fertilizer to grow the biomass and there are related environmental and social impacts that must be taken into account.

The IPCC's modelled pathways for 1.5°C indicate the need for up to 7 million km2 of land for bioenergy in 2050 (in comparison, the total land area of the European Union is ~4.5 million km2). Scaling up BECCS to this extent will have impacts for food security, land degradation, desertification and sustainable development.[37]

Although most of the IPCC's mitigation pathways include substantial deployment of BECCS, a small number of modelled pathways are able to limit warming to 1.5ºC with minimal dependence on BECCS (land area below <1 million km2 in 2050) and other CDR options. However, these pathways require much steeper and earlier emissions reductions.



RISKS

BECCS

PERMANENCE

Permanent storage can be achieved if the CO_2 produced during the combustion of the biomass is captured and securely stored.

GHG REMOVAL POTENTIAL

Depends on how much land society is prepared to devote to biomass production. See scalability and other enviro/social impacts.

SCALABILITY

There are few large-scale BECCS projects. The limiting factor of BECCS is the supply of biomass.

Given the enormous land requirements, and related social and environmental issues, it is highly questionable whether BECCS could be scaled up to the extent modelled in many of the IPCC1.5C scenarios.

COST

Varies widely with reported costs ranging from $15-400 / tonne.[38]

OTHER ENVIRO/ SOCIAL IMPACTS

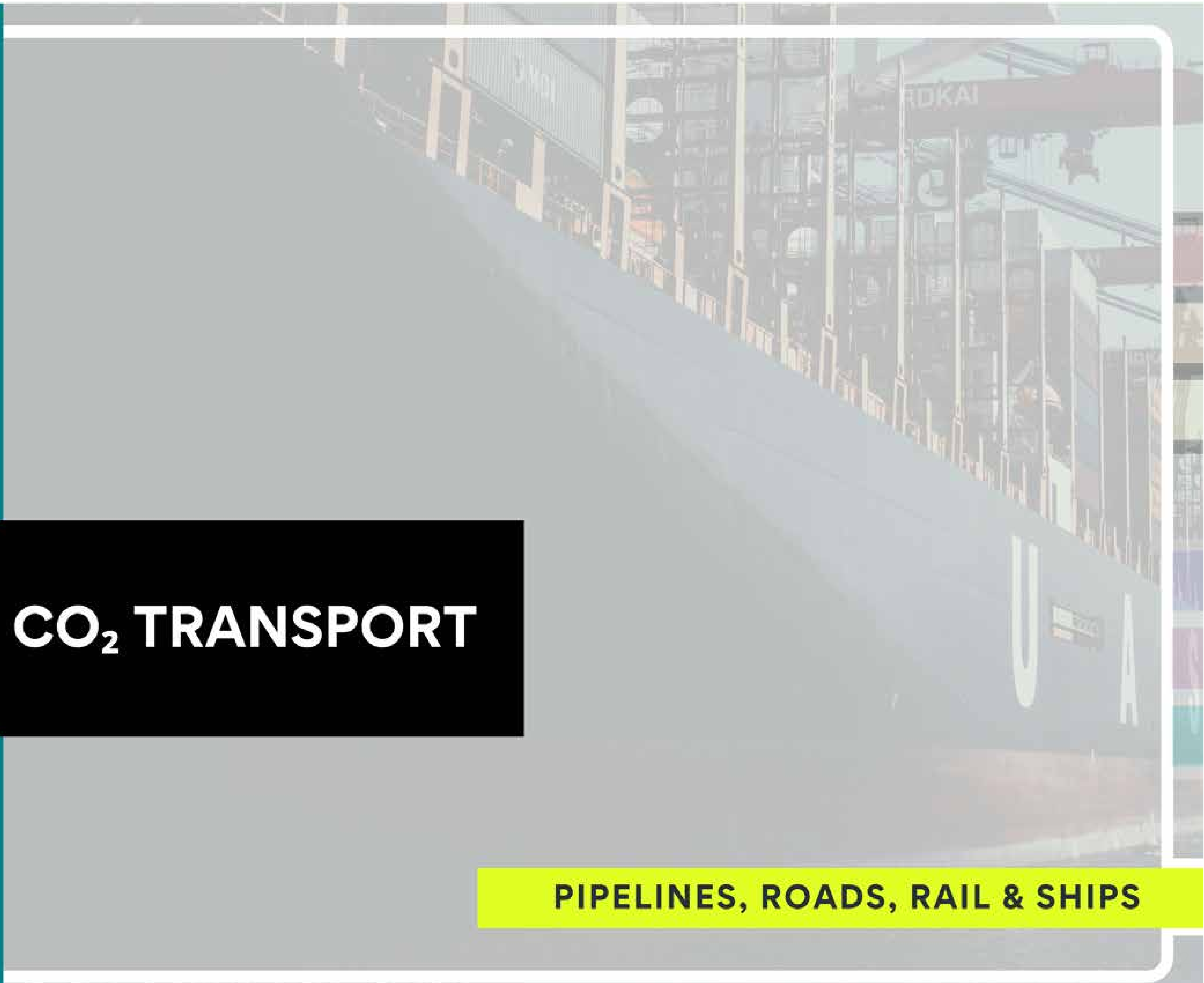
Devoting large areas of land to bioenergy crops may raise food prices, alter habitats and threaten biodiversity.

·Moving communities for land conversion threatens livelihoods and human rights.

Growing dedicated bioenergy crops would increase demand for water, while increased fertilizer use could further stress nitrogen-saturated ecosystems. Land conversion for growing biomass could release carbon stored in soils or existing biomass.[39]

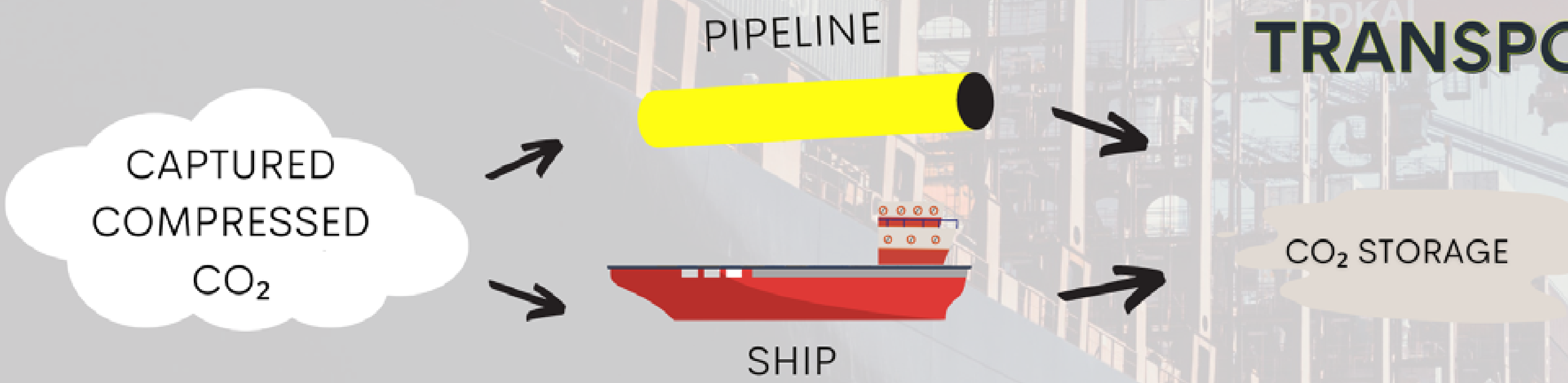
Even if the CO_2 is removed, combustion of biomass and biofuels creates local air pollution.

CO_2 TRANSPORT



PIPELINES, ROADS, RAIL & SHIPS

CO_2 TRANSPORT



Once CO_2 is captured, it must be compressed, transported, and stored. Pipelines are the usual method for transporting large amounts of CO_2 for distances up to around 1,000 km. For smaller quantities (less than a few million tonnes of CO_2 per year), or to transport the CO_2 overseas, the use of ships is an option.

A transportation infrastructure that carries CO_2 in large enough quantities to make a significant contribution to climate change mitigation will require an enormous network of pipelines. One researcher estimated that at the scale of 1 Gt removal, the volume of CO_2 would require a pipeline infrastructure that exceeds the current global oil handling infrastructure.[40]

Risks:

Significant energy is required to compress CO_2 and maintain high pressure throughout pipelines.

Siting routes for CO_2 pipelines is likely to be a challenge, and must respect the Free, Prior and Informed Consent of Indigenous Peoples.

CO_2 leaking from a pipeline forms a potential physiological hazard for humans and animals.[41] The risk of accidents and/or failure of CO_2 pipelines and marine transportation systems is considered to be comparable to long-distance oil and gas pipelines and marine transportation of oil.

A CO_2 pipeline in Mississippi ruptured in 2020, sickening dozens of people.[42]

CARBON STORAGE

GEOLOGICAL SEQUESTRATION

CARBON MINERALIZATION

DEEP OCEAN STORAGE

GEOLOGICAL CO_2 STORAGE

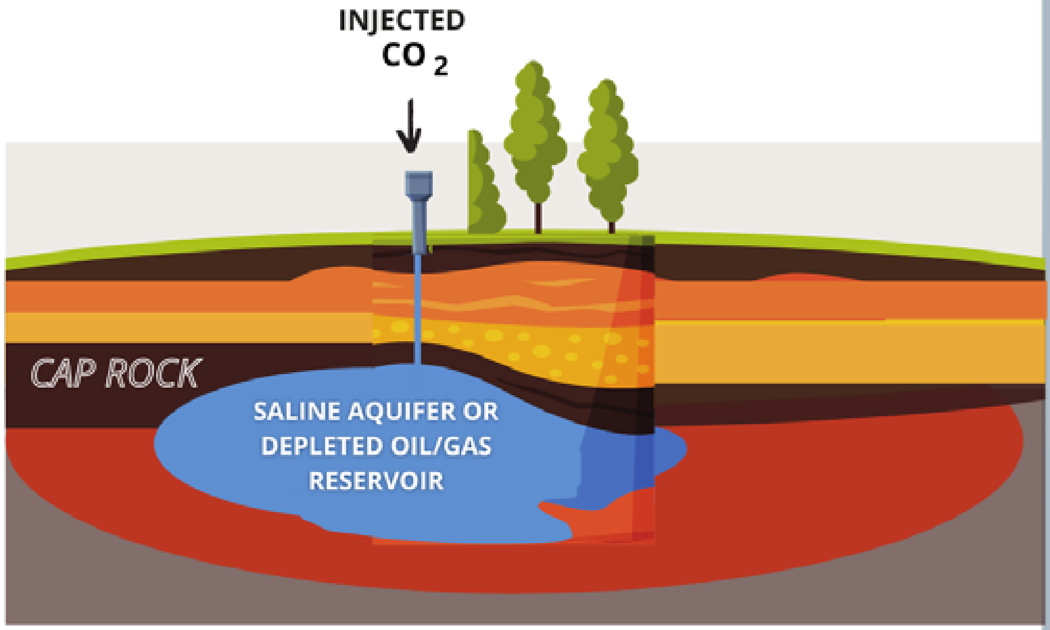
CO_2 can be permanently stored in depleted oil and gas reservoirs, deep coal seams or saline aquifers.

To do so, captured CO_2 is compressed into a supercritical fluid and injected into a well. The well must be deep enough that the CO_2 remains in a supercritical fluid form- usually more than 1km underground. Impermeable layers of sedimentary rock (cap rock) act as a structural trap, preventing the CO_2 from rising back to the surface.

To ensure that CO_2 is not re-released to the atmosphere, CO_2 storage sites must be designed to confine the injected CO_2 for geological time scales.

Risks could come from leaking injection wells, abandoned wells, leakage across faults underground, and ineffective confining layers. Leaks can affect ground water and mineral resources and have lethal effects on plants and subsurface creatures.[43] Leaks are difficult to detect.

A 2005 IPCC report says the fraction of CO_2 retained in well-sited, designed and maintained geological reservoirs is “very likely” [above 90% certainty] to exceed 99% over 100 years and is likely [above 60% certainty] to exceed 99% over 1000 years. However, even very low leakage rates over long periods of time could negate the climate benefits of NETs.[44]



RISKS

GEOLOGICAL CO_2 STORAGE

PERMANENCE

Leakage, while unlikely if appropriately regulated, could re-release CO_2 into the atmosphere.

Even very low leakage rates over long periods of time could negate the climate benefits of NETs.

Leakage is difficult to detect

ENERGY NEEDS

Energy is required for transport of the CO_2 from capture site to the injection wells, as well as for the actual injection into the wells.

SCALABILITY

There are challenges associated with upscaling more than 100 times, which would be necessary to reach the scale of $GtCO_2$/year.

OTHER ENVIRO/ SOCIAL IMPACTS

From a local point of view (i.e. a few kilometers around the storage site), concentrated CO_2 leakage could be harmful for people and livestock.

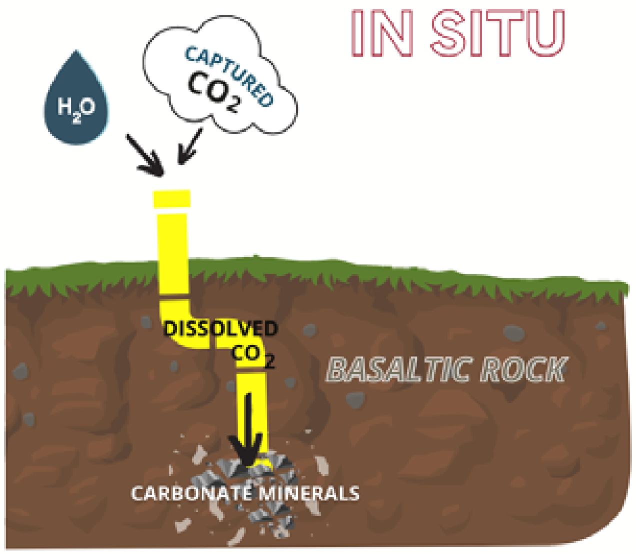
Leaks, although unlikely, could also affect ground water and mineral resources and have lethal effects on plants and subsurface creatures.

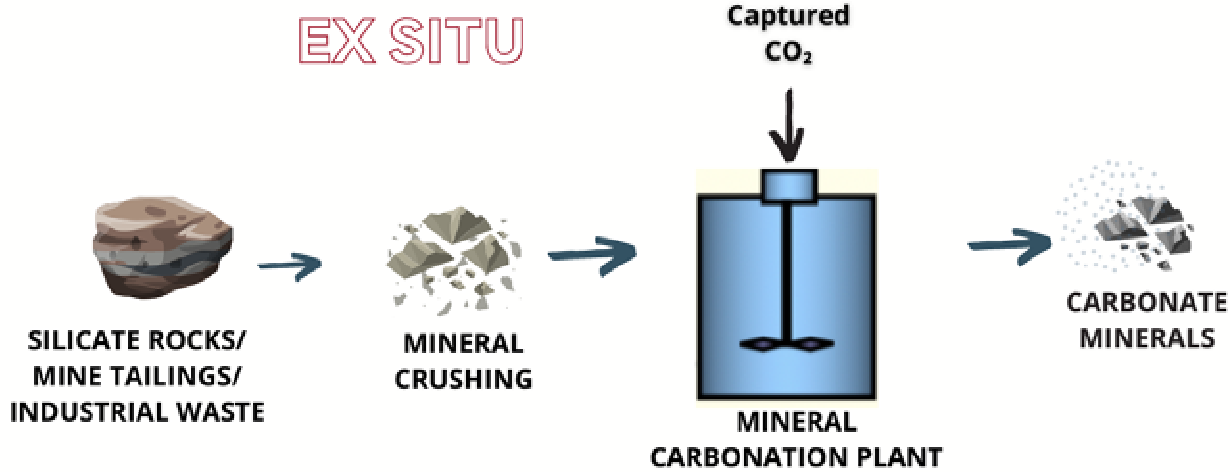
Old oil wells and mines can be "recycled" for geological CO_2 storage; however additional land would be required if new storage wells are needed.

MINERALIZATION

Carbon mineralization refers to the process by which certain minerals react and form a bond with CO_2 to form inert carbonate rock.

There are three main methods. *In situ*, where dissolved CO_2 is injected deep underground and reacts with minerals to form carbonate rock. *Surficial*, where CO_2 is exposed to broken pieces of rock (for example, mine tailings or smelter slag) at the surface. And Ex *situ*, where silicate rocks or industrial waste are ground to small particles and combined with captured CO_2 in a high temperature and pressure reaction vessel to form carbonated products.





Natural mineral carbonation is slow; hence energy-intensive preparation of the solid reactants to achieve faster conversion rates is required.

Injecting CO_2 deep underground risks triggering earthquakes, whereas surficial carbonization risks pollution of soil, water[45] and air and may indirectly result in habitat degradation. Huge volumes of water are required to dissolve the CO_2.

Mineral carbonation has virtually unlimited permanence.

It is more expensive than geological storage.

The technology is currently in the research stage, although certain applications using waste streams are in the demonstration phase. Several scientific challenges remain.

RISKS

CARBON MINERALIZATION

GHG REMOVAL POTENTIAL

The CO_2 removal potential of mineral carbonization is less than geological storage, when the full life cycle is considered, due to significant energy and chemical additives requirements.

ENERGY NEEDS

Significant energy requirements, especially for ex situ.

When accounting for the 10-40% energy penalty in the capture plant as well, a full CCS system with carbon mineralization would need 60-180% more energy than a power plant with equivalent output without CCS.[46]

SCALABILITY

There are a number of laboratory and small-scale demonstration projects for ex situ, but the technology has yet to be proven at scale. Although there is a large potential, the cost remains prohibitive. In situ is still in its infancy.

COST

Ex situ is limited by its high costs,[47] which range from \$50 to \$300 per tCO_2 sequestered. In situ's costs are also higher than for geological storage in sedimentary basins (\$17-50 versus \$8 per t CO_2).

OTHER ENVIRO/ SOCIAL IMPACTS

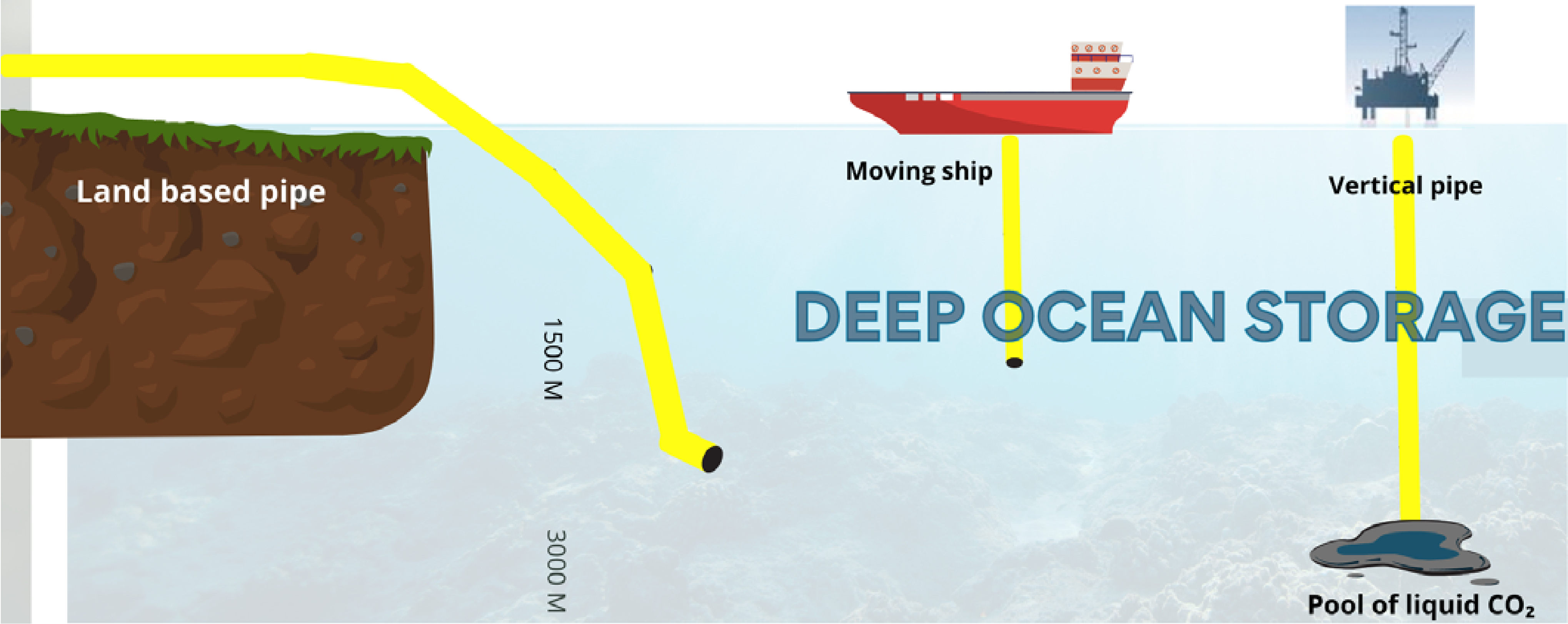
Carbon mineralization involves large-scale mining and associated environmental concerns: terrain changes, dust pollution exacerbated by potential asbestos contamination and potential trace element mobilization.
Risk of triggering earthquakes for in situ.
Risk of air, water and soil pollution, and habitat[48] degradation for surficial.
Large water requirements.

Captured CO_2 could potentially be injected into the water column below 1,000 meters via a fixed pipeline or a moving ship, or deposited via a fixed pipeline or an offshore platform onto the sea floor at depths below 3,000 m where CO_2 is denser than water and is expected to form a "lake" that would delay dissolution of CO_2 into the surrounding environment.

The dissolution of CO_2 may cause enhanced acidification of sea water with negative impacts for marine life.

There is a risk that ocean currents could bring CO_2 to surface sooner than anticipated. Over centuries, ocean mixing would gradually result in CO_2 exchange with the atmosphere.There is no known mechanism that would cause a sudden or catastrophic release of CO_2.

Ocean storage is still in the research phase. The technology has yet to be demonstrated in a pilot plant.



RISKS

DEEP OCEAN STORAGE

PERMANENCE

CO_2 injected in plumes could be stored for hundreds of years; however, there is a risk that ocean currents could bring CO_2 to surface sooner than anticipated.

ENERGY NEEDS

Energy would be required for transport and shipping of captured CO_2 to the injection site.

SCALABILITY

There have been small-scale field and laboratory experiments but ocean storage has not yet been deployed or thoroughly tested.

GHG REMOVAL POTENTAL

Given the size of the oceans there is no physical limit on the amount of CO_2 that could be stored in the oceans, however eventually the oceans would equilibrate with the atmosphere.[50]

OTHER ENVIRO/ SOCIAL IMPACTS

Injection up to a few $GtCO_2$ would produce a measurable change in ocean chemistry in the region of injection, whereas injection of hundreds of $GtCO_2$ would eventually produce measurable change over the entire ocean volume. This change in pH would pose risks for marine organisms[49].

2.3 Summary of technologies – Risks and limitations

There are considerable challenges and constraints associated with negative emissions technologies and CO_2 storage options, as presented in the figures above. To summarize:

- DAC technology has yet to be demonstrated at a large scale. It is water- and energy-intensive as well as expensive. Unless DAC is powered by renewables and the captured CO_2 is permanently stored it will not achieve negative emissions.
- Ramping up BECCS to the scale suggested in some 1.5 °C pathways would require a phenomenal amount of land, which could have serious repercussions for food security, biodiversity, land degradation, desertification, sustainable development, livelihoods, Indigenous rights and human rights.
- While CCS, CCU and CCUS (e.g. point source capture) may help reduce emissions from power and industrial plants, they are not negative emissions technologies, and the capture rate is far from 100%. When the captured CO_2 is used for enhanced oil recovery, which is frequently the case, it can give rise to increased emissions when the full life cycle is considered.
- For NETs to play a significant role in achieving global net-zero targets, gigatonnes of CO_2 would need to be captured, transported and stored. The CO_2 transportation infrastructure required would be roughly equal in scale to today's oil and gas pipeline and marine transport networks, with similar risks of accidents and land rights challenges.[51]
- There are uncertainties regarding the ability to scale geological sequestration to the magnitude necessary, and there is a small risk of leakage from geological storage sites – but even very low leakage rates over long periods of time could negate the climate benefits of NETs.
- Carbon mineralization has yet to be proven at scale. It requires significant amounts of energy and water, is very expensive, and depending on whether it's in situ, ex situ, or surficial, there is a risk of triggering earthquakes or contributing to land degradation and pollution.

III. What is the appropriate role for NETs in addressing global climate change?

If NETs are going to be a part of the solution to climate change, there are several fundamental questions and important considerations that need to be addressed.

3.1 Does one tonne in equal one tonne out?

There is a common assumption when balancing CO_2 emissions with CO_2 removals that "one tonne in equals one tonne out." This assumption has been called into question in recent studies however, and based on current science it appears that the assumption is too simplistic and therefore relying upon it to calculate a carbon "balance" could be dangerous.

A recent study published in Nature Climate Change, for example, showed that the climate response to CO_2 emissions and removals is actually "asymmetrical" – in other words, the climate response to CO_2 emissions is not equal and opposite to CO_2 removals of the same magnitude, due to the non-linear nature of the Earth system and carbon cycle feedbacks.[52] Other studies have also demonstrated the need to quantify the interactions between the climate, carbon cycle and anthropogenic NETs, noting that the combined effect of anthropogenic and natural sources and sinks can change over time, sometimes resulting in positive and sometimes negative changes in atmospheric CO_2 concentration.[53]

According to the most recent IPCC report on the physical science basis of climate change (2021), "The atmospheric CO_2 decrease from anthropogenic CO_2 removals could be up to 10% less than the atmospheric CO_2 increase from an equal amount of CO_2 emissions, depending on the total amount of CDR."[54] The best guess of the true "balance" is 1.1 tonnes of CO_2 removals per tonne of CO_2 emitted. So it would be prudent to ensure that at least 1.1 tonnes of CO_2 are removed for each tonne of CO_2 emitted. That said, the scientific uncertainties around the concept of "balance" reinforce the perspective that any reliance on CO_2 removals to achieve net zero should be limited.

It is also important to consider whether a tonne removed now is equivalent to a tonne removed later, and/or whether a tonne removed here is equivalent to a tonne removed there. Removing CO_2 years from now may be less effective than removing CO_2 now, as delays can result in overshot targets and increased climate impacts that push the burden of the climate crisis onto future generations. Removing CO_2 in certain locations might also be more (or less) beneficial than other locations, given the local conditions and social justice and environmental impacts that can result.

> While "a ton is a ton" might be a useful abstraction for creating and apportioning carbon budgets, the argument goes, it is a poor guide in the design of climate policy, where different options for mitigation and their distribution in time and space correspond to radically different values, socioeconomic effects, and risk profiles.[55]

3.2 Do NETs always achieve negative emissions?

Although the purpose of NETs is to *reduce* the concentration of atmospheric CO_2, NETs can actually result in a *net increase* in emissions when the full life cycle is considered.

To ensure that NETs truly achieve negative emissions, it is vital that all emissions produced by the process are accounted for, including upstream and downstream emissions.

> In order to assess whether a process adds to or reduces atmospheric CO_2, ...it is necessary to look at the entire capture and storage process, and to compare the total quantity of CO_2 emissions with the quantity of CO_2 removed and stored. This requires a full life cycle analysis (LCA).[56]

A failure to account for some of the associated emissions can result in misleading or incorrect claims that an industrial NET facility results in negative emissions when in fact it may emit more emissions than it removes. This is not to suggest that NETs cannot achieve negative emissions, but to sound a cautionary note against assuming that any project that sucks CO_2 from the atmosphere will result in an overall CO_2 removal.

To achieve negative emissions, the captured CO_2 must be permanently stored; however, it often isn't.

Instead of *storing* captured CO_2, the CO_2 is sometimes utilized to make a variety of products, including synthetic fuels, chemicals, building materials, carbonated drinks, and cement. Generally speaking, the demand for captured for CO_2 for these uses is insignificant in a climate context, because utilization volumes fall far short of sequestration needs.[57] And many of these uses would result in the CO_2 eventually being released back into the atmosphere, thereby cancelling out the negative emissions that would have been achieved.

Most captured CO_2 is in fact used for enhanced oil recovery (EOR). EOR is the injection of pressurized CO_2 into existing oil and gas reservoirs to force out more fossil fuels. EOR has been in practice for decades, although much of the injected CO_2 has originated from natural CO_2 reservoirs under the Earth's surface, rather than from captured CO_2. It has been estimated that 90-95% of the injected CO_2 for EOR remains underground, trapped in geological formations. Yet EOR, by design, increases fossil fuel production. Since those fossil fuels are subsequently burned resulting in emissions, this use of technologies which would otherwise be NETs over their life-span often result in an increase in emissions.

Currently there is little financial incentive for companies to capture and store their CO_2 emissions, and even less to remove CO_2 from the atmosphere. So EOR is the most common industrial method for using CO_2 at a large-scale because it is profitable. But that doesn't make it climate friendly.

To be an effective climate solution, captured CO_2 must be stored permanently and not used to further increase fossil fuel production. As noted in a letter from 47 Canadian organizations to the Government of Canada, "While EOR makes business sense for the fossil fuel industry.... It is not a winning strategy for the climate."[58]

In addition to the fundamental issue of whether the captured CO_2 is permanently stored, another factor that impacts the overall emissions balance of an industrial CDR project is the energy required to run the technology (including any upstream and downstream power needs) – and the power source used.

DAC is extremely energy intensive. In practice, much of the DAC currently in use is powered by fossil fuels. That, in combination with the fact that most DAC-captured CO_2 is used and not stored, means that almost all of the DAC developed to date actually results in more CO_2 than it removes, "emitting from 1.46 to 3.44 tons of CO_2 for each ton removed."[59]

Using renewable energy to power DAC would increase the technology's ability to achieve net removals of CO_2. But whether renewable energy *should* be channeled to power DAC is an important question. There is an opportunity cost, since society also requires an enormous amount of renewable energy to reduce carbon emissions from homes, industry, businesses and transport. Although DAC powered by renewables would achieve larger emissions reductions than DAC powered by fossil fuels, it has been estimated that it would require *all* of the wind and solar energy generated in the United States. in 2018 to power enough DAC to capture just 0.1 $GtCO_2$ (for perspective, the US emitted 5.28 GtCO2 in 2018).[60,61]

3.3 How fast and far can we ramp up NETs?

The rhetoric around NETs sometimes seems to imply that with the right funding or financial incentives, a magic wand could be waved, and facilities built, that would pull virtually unlimited amounts of CO_2 out of the atmosphere. The reality, of course, is that there are constraints that will affect the scalability of NETs.

Studies suggest that the *theoretical* limit on how much CO_2 can be captured and stored is large; however, there are very real constraints on NETs, related to energy, water, land and other resource use. There are engineering and other questions about whether large-scale deployment would work and, even if those issues are resolved, a limit to the speed with which the infrastructure can be physically built.

One constraint is the time required to roll out NETs on any significant scale. The future regulatory requirements still need to be developed, but even the task of finding and assessing appropriate storage sites for sequestration has been estimated at 3-4 years,[62] which would presumably precede the years required to build a NETs facility and/or lay pipes laid to bring captured CO_2 from the facility to the storage location. Shortages of steel and/or labour could contribute to further delays, as could technical difficulties, such as those experienced by the Gorgon Carbon Capture and Storage facility in Australia.[63]

The challenges with ramping up CDR are exacerbated by the fact that addressing the climate crisis requires the rapid build-out and retrofitting of *other* infrastructure, both to reduce emissions and prepare for the impacts of climate change. Some researchers have noted a gap in the academic literature aimed at understanding the complex interplay between the use of these different technologies and the available resources.

Energy use provides a particularly useful example. As noted, to achieve negative emissions, NETs will need to be powered with renewable power; but as a consequence, there will be less renewable energy available for society's other power needs, such as heating buildings, electrifying transportation and other measures to decarbonize the economy. One article commenting on the lack of academic studies directly considering the relationship between energy systems and NETs called for:

> Energy systems modeling efforts with high spatiotemporal and technological resolution, to understand: (1) the role of CDR deployment in regional energy demand (DACCS) and energy supply (BECCS) curves, and (2) potential feedback loops between energy market prices and cost/carbon efficiencies of CDRs options.[64]

As highlighted in section 2.2, similar challenges exist for the immense amounts of land needed for large-scale BECCS. Although BECCS features prominently in many climate stabilization scenarios, the area of land required to sequester that much carbon is almost certainly unsustainable. To deliver the level of carbon removal needed in some scenarios, up to several million square kilometers of land would need to be allocated for BECCS. Large-scale land acquisitions and conversions have been historically entangled with various forms of colonization, and it is unclear how this much land could be devoted to BECCS whilst fully respecting, protecting and fulfilling human rights, and particularly Indigenous rights. Converting this much land to BECCS would also have serious implications for biodiversity and food security.

There are very few studies that attempt to quantify systemic or economy-wide constraints on the build-out of NETs. One paper noted that most academic discourse of DAC assumes that DAC "can be scaled-up solely subject to technological learning but not subject to biophysical constraints." That paper is one of the few we found that gave estimates (though very rough and wide ranging) of technically feasible global BECCS and DAC removals by 2050 (0.5–2GtCO_2/yr and 0.5–5GtCO_2/yr, respectively),[65] suggesting that the IEA's estimate of 2.4 GtCO_2/yr by 2050 is potentially achievable. However, it is clear that considerably more research is required to confirm these estimates.

3.4 Fair share – How much CDR should Canada be responsible for?

The first principle of the UN Framework Convention on Climate Change affirms that countries should protect the climate system "... on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities" and that developed countries should take the lead in combating climate change.[66]

Per capita, Canada is one of the largest greenhouse gas emitters in the world – and has been since the early 1900s. Despite being home to less than half a percent of the global population, Canada has emitted approximately 2% of the greenhouse gas emissions currently in the atmosphere, which puts us in the top ten emitting countries.[67] Canada has reaped enormous economic benefits while polluting the global atmosphere, and thus bears a significant responsibility for contributing to the climate crisis. As a wealthy country, Canada also has the capacity to act. Canada must do its "fair share" and shoulder a greater burden of climate mitigation than the global average.

The IPCC has stated that in order to limit global temperature increase to 1.5 °C, the planet must achieve net-zero CO_2 emissions by 2050. That is a global average. To achieve that goal while respecting the principle of equity, wealthier countries like Canada would need to achieve net zero earlier than 2050, to allow less wealthy countries to achieve net zero a little later.

Similarly, the IEA's modelling of a 1.5 °C future would see:

> CO_2 emissions in advanced economies as a whole fall to net zero by around 2045 and these countries collectively remove around 0.2 $GtCO_2$ from the atmosphere in 2050.

Fortunately, the *Canadian Net-Zero Emissions Accountability Act*, while setting net zero by 2050 as the *latest* year by which the country must achieve net-zero emissions, expressly leaves open the possibility of achieving the net-zero goal *earlier* than 2050.

If the IPCC and the IEA are correct that the world needs to ramp up global industrial CDR to 2-7 $GtCO_2$[68] per year by 2050 in addition to dramatically reducing greenhouse gas emissions, we must ask ourselves *which* countries should be responsible for CDR, and how should the share be allocated?

Recent academic papers tackle this challenge by applying different ethical lenses to assigning a fair share for CDR responsibility, for example, on the basis of a country's cumulative emissions per capita, the ability to pay,[69] and formulas that combine both factors.[70] There is also the question of which countries have the necessary resources, including land, biomass and underground reservoirs, to capture and sequester CO_2 at a climate-significant scale. These papers find that wealthier countries bear a much larger responsibility to build CDR, with one study estimating that Canada, in an allocation based on historic responsibility, should build CDR facilities to capture a cumulative quantity of 17.77 $GtCO_2$ from the atmosphere by 2100 (via both industrial CDR and nature-based approaches).[71]

It must be emphasized, however, that although these papers highlight that Canada has a responsibility to address its past emissions, the papers are not suggesting that this level of CDR is possible or desirable in terms of ecological impact, resource use, etc. Furthermore, if Canada does build out CDR to compensate for its historical emissions, Canada should *not* be entitled to emit more greenhouse gases because of this CDR.

Regardless, it seems clear that for Canada to address its historic and ongoing emissions and contribution to causing climate change, the country must achieve net zero *before* 2050 by rapidly reducing emissions to near zero, and likely by also removing some CO_2 from the atmosphere to draw down historical emissions and to compensate for emissions that cannot be feasibly eliminated. If some NETs are needed to "neutralize" hard to decarbonize Canadian emissions, such use should be kept to a minimum.

3.5 Who should pay for CDR?

Building out NETs to the levels required to limit global temperature increase to 1.5 °C or even 2 °C in a manner consistent with the IPCC and IEA modelling will require considerable resources. One paper examining CDR deployment to achieve 2 °C under IPCC scenarios describes the undertaking as "an atmospheric GHG restoration Manhattan Project" and predicts that it "might consume up to a third of general government expenditure in advanced economies."[72]

Not surprisingly, a growing body of academic literature asks how we are going to create the financial incentives necessary to ramp up a barely existing industry at an unprecedented rate. They are quick to point out that this will require government intervention, because there are few existing incentives or co-benefits that would justify dramatic private investment in CO_2 removals from the air and burying it underground.[73]

These papers largely reject the view of CDR as a "low-cost alternative" to reducing greenhouse gas emissions – that is, they do not accept that industries that find it too expensive to reduce their greenhouse gases should instead be allowed to "offset" their continued emissions through CDR.

> If we buy into thinking of carbon removal technologies as substitutes for reducing carbon output, then industrial interests have already won: they have set the narrative and the framing, where carbon capture exists so that they can continue to emit. But we should demand more from these technologies.[74]

As we have seen, IPCC reports indicate that CDR should only be used for a narrow range of purposes, and these do not include a "if you can pay for it, you can continue to emit" scenario.

Several writers propose that CDR should be viewed as a "public service", analogous to waste disposal.[75] According to this view, governments should fund and build the infrastructure necessary for CDR, achieving removal goals independently from commercial efforts to reduce greenhouse gases.

> Lawmakers should approach atmospheric carbon dioxide reduction as public service to meet a societal need, which is to achieve an absolute reduction in atmospheric CO_2. This means that dedicated sequestration—not sale—of CO_2 is the public policy path. From the perspective of public lawmaking, captured CO_2 must be regarded as a pollutant rather than a commercial commodity.[76]

It should be noted though, that public funding of CDR as waste disposal could still amount to a subsidy of the fossil fuel industry if it is used to justify a delay in emissions reductions, even if not directly tied to the offsets of a particular industry. However, a polluter pays approach in which public CDR is paid for through industry taxes and/or a carbon tax, while industry is held to aggressive emissions reductions requirements, could realize the potential of CDR to protect the public interest. Even in this situation though, there is an opportunity cost, and the money raised through a tax may be better used elsewhere.

> Other papers argue in favour of a "polluter pays" or "producer responsibility" approach, in which industry is required to fund or realize a particular amount of CDR independent of, and in addition to, its obligations to reduce its greenhouse gas emissions. This has variously been called a Carbon Removal Obligation,[77] or Carbon Take Back Obligation,[78] among other names, but essentially involves imposing an obligation on polluters/emitters/producers to pay to clean up the greenhouse gases that they have caused to enter the atmosphere.

> Carbon debt would enter the balance sheets of firms as a physical liability in tonnes (t) CO_2—a carbon removal obligation, for which interest payments would be due. This chain of legal liabilities across layers of public and private actors reduces the moral hazard that governments would ultimately pick up the bill for net emission removal, and limit the issuance of CROs to debtors who are reluctant to fulfil their (interest) obligations.[79]

Researchers propose various ways that this debt obligation could be satisfied, including government issued "Certificates of Storage" along with a defined mandate to permanently store an increasing percentage of produced carbon every year[80], and payment into a fund "in the style of a nuclear decommissioning trust fund or a sovereign wealth fund"[81] that would pay for CDR. After an initial ramp-up period, the requirement to remove carbon would cover not just production (direct) emissions but all emissions associated with the production and use of the fossil fuels. This approach would provide a path to ramp up CDR, but would not prioritize hard to decarbonize industries or atmospheric restoration.

The academic literature also explores the related and thorny problem of who is financially and legally responsible if CO_2 leaks after it has been stored – years, decades or even centuries later. Similar issues can arise if the CO_2 escapes during transportation.[82] It has been suggested that uncertainty around the liability for long-term leakage has deterred industry from investing in CCS,[83] which, if correct, may suggest that carbon storage is less permanent than industry sometimes suggests. Academics have recommended different approaches to ensuring that the costs of monitoring for leaks and addressing such leakage rest with the companies that store the carbon, to address the challenges of long-term uncertainty.

The costs of NETs are considerable, and can amount to subsidies to industry if the public ends up paying for them, particularly if the technologies are then used in industries and processes that are not essential to the well-being of the public and/or where decarbonized alternatives exist.

3.6 What is the appropriate role for NETs in addressing global climate change? Conclusions and recommendations

Given the need to swiftly reduce emissions in line with the 1.5 °C trajectory, and the significant risks and limitations associated with NETs, we recommend *not* relying on NETs to meet climate targets. Instead, it is important to reduce emissions to as close to zero as possible by transitioning from fossil fuels to renewable energy, among other measures.

NETs should be used sparingly, with their application limited to compensating for emissions from industries or functions that are considered absolutely essential and extremely difficult to decarbonize, as well as Canada's historical emissions. Moreover, safeguards are vital to prevent environmental and social impacts, and to ensure the storage is permanent.

Based on our research, we have identified a number of principles and associated recommendations to guide the use of NETs:

Principle #1 – Because of the risks, limitations and uncertainties, use NETs only for atmospheric restoration (reversing historic emissions) and to compensate for emissions deemed essential and extremely difficult to decarbonize.

- Emissions *reductions* must be prioritized over a reliance on future, and as yet unproven, NETs to meet climate targets.
- Any proposal to use NETs to offset emissions must demonstrate that no alternatives exist, and that the emissions are essential and no decarbonized alternatives exist.
- NETs must not be used to justify the continued expansion of oil and gas extraction and other industries inconsistent with a low carbon future.

Principle #2 – Ensure that NETs result in actual and permanent removals of CO_2 from the global atmosphere, resulting in net-negative emissions.

- Transparent monitoring, reporting and verification of the carbon sequestration achieved by CDR is critical to provide accurate accounting of carbon sequestration.
- Full life-cycle assessments of CDR technologies are needed to assess their efficacy in reducing emissions. Policies governing the use of NETs must ensure that the amount of CO_2 removed significantly exceeds the amount of CO_2 emitted by the process over the entire life cycle.
- Since one tonne of CO_2 removal almost certainly does not equal one tonne of avoided emissions, require at least 1.1 tonnes of removals for every 1 tonne of emissions.
- Captured CO_2 must be stored permanently in order to meet climate goals, rather than used for Enhanced Oil Recovery or any other processes that run counter to climate goals.
- NETs should be powered with *surplus* renewable energy, to ensure that NETs achieve negative emissions, while ensuring enough renewable energy is available to decarbonize other sectors.

Principle #3 – Consider and manage the land, environmental, energy, social and cultural impacts of NETs.

- Careful consideration of CDR land, energy and water use is necessary to inform siting and minimize resource impacts.
- NETs, and especially BECCS, should not be used in ways that would result in food insecurity, land use conflicts or detrimental biodiversity impacts.
- The UN Declaration on the Rights of Indigenous Peoples, especially the principles of self determination and Free, Prior and Informed Consent, must be upheld. This is true for all NETs projects and related infrastructure, but is particularly relevant for projects that require land.

Principle #4 – Ensure that polluters pay for the limited NETs that are needed.

- Hold polluting industries accountable for the costs of atmospheric restoration.
- Reject the "if you pay for NETs you can continue to pollute" approach.
- Ensure that government has an active role in focusing use of NETs on atmospheric restoration and limited use in essential, hard to decarbonize industries.

IV. Applying the Principles to NETs in Canada

Having identified, through our literature review, four principles that should inform the use of NETs in Canada, we will now consider how those principles relate to current and future climate laws and policies in Canada. We will review what we know about Canada's intentions to use NETs to meet its climate targets, and how Canada might make use of NETs while minimizing risks and drawbacks.

There is limited information available regarding the Canadian government's intended use of NETs; however, we can contemplate how CDR might be taken into account when establishing targets and plans under the *Canadian Net-Zero Emissions Accountability Act* (CNZEAA), as well as in the assessment of the climate impacts of particular projects.

4.1 Contemplating NETs in CNZEAA targets

As noted above, a net-zero emissions target can be achieved through various combinations of emissions reductions and removals. For example, the net-zero target could be achieved mostly through absolute reductions in greenhouse gas emissions, or alternatively, may rely heavily on NETs. What a net-zero society should look like is very much in the eye of the beholder, depending on the beholder's sense of what is achievable.

The CNZEAA states that the 2050 target should guide the government's climate actions over the coming decades, resulting in "ambitious action … in support of achieving net-zero emissions in Canada by 2050…."[84] But if successive governments envision the pathway to the goal differently in terms of emissions reductions versus removals, will Canada realistically achieve its target? Does it provide the "accountability" that the Act promises in its name?

To be useful as a goal, the net-zero target must not be interpreted as meaning any and all combinations of emissions reductions and removals that collectively "balance" to net zero. CNZEAA requires that successive governments work toward the same goal and that there be consistency in the emissions path to that goal. CNZEAA will not function if one government assumes that the net-zero target requires emissions reductions as quickly as possible, and a subsequent government assumes that emission levels can increase or plateau because NETs will save us down the road. Principle #1 provides important guidance. Governments must use NETs only to address emissions from essential industries that cannot be decarbonized and to restore the health of the atmosphere. It would be unrealistic and inequitable for Canada to delay dramatic emissions reductions while promising a rapid increase in NETs. CNZEAA should be amended to provide greater clarity and specificity to ensure this doesn't happen.

As a result of CNZEAA's net-zero goal, we have seen a shift in how Canada describes its 2030 climate targets, from absolute reduction targets to "net" targets. Canada's first Nationally Determined Contribution, filed under the 2015 Paris Climate Agreement in 2017, committed to an absolute reduction from base-year emissions of "30 percent below 2005 levels by 2030" (i.e. reduce "total economy-wide emissions to 523 Mt in 2030.") [85] In contrast, Canada's current Nationally Determined Contribution, filed in 2021, commits to a 40-45% reduction in greenhouse gas emissions relative to 2005 levels, including 27 Mt of reductions and removals attributable to changes in land use (including planting trees, nature-based solutions, etc.).[86] NETs are mentioned as a topic of research only, but CCS does play a prominent role.

CNZEAA does include some flexibility that could allow for greater ambition. For example, the CNZEAA expressly leaves open the possibility that Canada can achieve net zero prior to 2050, and gives the Minister discretion in setting targets and plans. In addition, CNZEAA repeatedly requires the Minister to consider not just the 2050 goal, but also Canada's international climate commitments, which arguably favour more ambitious action (especially when Canada's "fair share" is considered). This leaves the door wide open for Canada to adopt a precautionary approach – only using NETs to compensate for historical emissions and emissions from a small number of hard to decarbonize industrial processes/sectors. There is a risk, however, due to the vagueness of the net-zero target, that it could still be used to justify a reliance on NETs that goes beyond the limited role of NETs suggested by Principle #1.

Interestingly, while many countries have settled on a 2050 net-zero emissions commitment, some countries have, through legislation or policy, committed to an earlier date and/or to be emissions negative by 2050.[87] Others have stipulated that most of their “net” target will be achieved through absolute emissions reductions. For example, Sweden’s 2017 Climate Act does both, providing that:

> By 2045, Sweden is to have zero net emissions of greenhouse gases into the atmosphere and should thereafter achieve negative emissions. ... However, emissions from activities in Sweden must be at least 85 per cent lower than in 1990. Based on current population forecasts for Sweden, this means that emissions in Sweden will be less than one tonne per person by 2045.[88]

Similarly, some researchers have recommended setting separate absolute and NETs targets.

> To avoid substitution, and hence ensure negative emissions deliver the necessary additional carbon removal, we suggest that targets and accounting for negative emissions should be explicitly set and managed separately from existing and future targets for emissions reduction. Targets, timetables, accounting methods and incentives could then be clearly and explicitly tailored to the different approaches and technologies involved. This principle should apply to all levels of targets: international, national, local, organizational, and sectoral.[89]

These approaches would help Canada meet its climate targets while reducing its emissions to the greatest extent possible in accordance with its historic responsibility and obligations to do its fair share.

The challenges associated with net-zero climate goals should also be considered by other levels of government that have adopted, or might be considering, net-zero climate goals.

4.2 NETs in government plans

One of the strengths of CNZEAA is that it does not just set a 2050 target, but also requires Canadian governments to set short-term, milestone targets ten years in advance and every five years, beginning with the 2030 target, to define how Canada will work towards the 2050 target. The Act also requires the development of plans to achieve those milestone targets. Both the targets and the plans are supposed to be based on the best available scientific information and advice from an expert Net-Zero Advisory Body, among other factors.

This structure means that the milestone targets (and/or the plans to achieve them) could (and should) establish what portion of the target, if any, would be achieved through NETs. In keeping with Principle #2, and the need to ensure that NETs deliver actual reductions, near-term targets and plans should only include NETs that are demonstrated to be scalable over the life of the plan.

Long-term planning however, will be linked to the setting of new milestone targets. While CNZEAA requires that each successive target be more ambitious than the previous target, and at least as ambitious as the current Nationally Determined Contribution, the Act's "balance" or "net" approach raises questions about what is meant by "more ambitious." Principles #1 and #2 require that a Minister prioritize actual emissions and limit the use of NETs to realistic levels and for appropriate purposes. It is inappropriate for future targets and plans set by a Minister to explicitly or implicitly downplay emissions reductions in favour of a dramatic ramp-up of removals, on the grounds that it is "consistent" with a pathway to net zero.

In addition to plans under the CNZEAA, other government agencies need to recognize the appropriate role and constraints of NETs in their planning. For example, *Canada's Energy Future 2021*, by the Canada Energy Regulator, recently considered six "net-zero electricity scenarios," all of which used some level of CCS, but one of which relies heavily on BECCS to achieve the net-zero target.[90] While the Canada Energy Regulator Report does recognize that there are "limitations in available biomass resources" that would limit BECCS to generating 6 Gigawatts of energy, it fails to consider, in accordance with Principle #3, what that level of BECCS would mean for land use, Indigenous rights, food security or any of the other factors that give rise to those limitations.

Except for the Green Party of Canada, none of the federal political parties have to date ruled out using NETs and CCS to justify the continued use of fossil fuels as Canada's major energy source, nor indicated any awareness of the real constraints on the use of NETS (Principles #1 and #3). During the recent federal election, the Conservative Party of Canada pledged to provide funding for DAC as part of its plan to address climate change while expanding the oil sands, optimistically promising that DAC would "reduce emissions in Canada and advance technology that Canada could soon be exporting to the world."[91]

Based on Principle #2 (NETs must actually achieve negative emissions), the requirement that government decisions made under the CNZEAA must be based on the "best scientific information available"[92] means that assumptions about future scaling up of NETs should be based on what is currently scientifically feasible, rather than optimistic assumptions about how future technology might develop. This should be the case for other government planning as well.

Additional legislation or amendments are needed to implement Principle #1 to ensure that CDR can *only* be used to compensate for historical emissions and emissions that are essential and extremely difficult to decarbonize. The government should undertake a transparent assessment of which processes it will require CDR for, and what that means in terms of the required scale and time-frame for the development of NETs. For all other processes, emissions should be reduced to zero as quickly as possible.

4.3 Government regulation and impact assessment

Currently Canada does not have clear laws regulating NETs. This is problematic because, as we have seen, DAC, BECCS and other technologies will not necessarily achieve negative emissions and can have huge environmental, social and other consequences. Further to Principle #2 (NETs must result in net negative emissions), if Canada will be relying on NETS in even a small way to achieve its net-zero target, the Canadian government must set out clear laws regulating how NETs should be sited, approved and monitored and how the CO_2 removals will be verified and accounted for.

Canada's *Impact Assessment Act* illustrates the many ways in which Canada's regulatory system is unprepared for NETs.[93] The *Impact Assessment Act* is a key Canadian environmental law that requires the government to evaluate and consider the environmental impacts of large projects; however, NETs projects do not currently appear in the list of projects that require assessment.[94] At present, then, there is no mechanism to implement Principle #3 (the consideration of the social, environmental and other impacts of large-scale NET projects). A similar gap seems to exist in some provincial environmental assessment laws, although there at least BECCS projects may be assessed if the projects generate large amounts of electrical power.[95]

For other large-scale projects that are assessed under the *Impact Assessment Act,* the Act requires the government to examine:

> ...the extent to which the effects of the designated project hinder or contribute to the Government of Canada's ability to meet its environmental obligations and its commitments in respect of climate change.[96]

Although enacted prior to the CNZEAA, the *Impact Assessment Act* will almost certainly be read alongside the CNZEEA with regard to "balancing" emissions to reach net zero.

The potential for project proponents to argue that emissions from a proposed project can be balanced through NETs seems clear, even before one reviews the government's draft *Strategic Assessment of Climate Change*, which sets out criteria for measuring the net greenhouse gas emissions associated with a project:

> Net GHG emissions = Direct GHG emissions + Acquired energy GHG emissions - CO_2 captured and stored - Avoided domestic GHG emissions - Offset credits[97]

"CO_2 captured and stored" is defined as "CO_2 emissions that are generated by the project and permanently stored in a storage project." It does not currently refer to NETs although it does include CCS. It is highly concerning that offset credits are stated to represent "one tonne of carbon dioxide equivalent reduced or removed from the atmosphere." As explained in Part III, this assumption is not consistent with the scientific literature and would undermine Principle #2 and the "balance" that we are trying to attain.

The logic of using NETs to offset emissions from a particular project also ignores Canada's historic responsibility and the obligations to remove carbon from the atmosphere discussed above in section 3.4 on "fair share." It assumes that there are no higher or better uses for the carbon removal than to facilitate new CO_2 emissions. Both assumptions are contrary to Principle #1, that removals should only be used to compensate for a narrow range of hard to decarbonize industries and to reduce CO_2 concentrations already in the atmosphere.

The approach to measuring greenhouse gas emissions described by the *Strategic Assessment of Climate Change* should be re-evaluated to prioritize actual reductions. In keeping with Principle #1, offsets and NETs should only be utilized when it has been demonstrated that there are no alternative ways to reduce emissions and that building the project is the highest and best use of any proven and permanent NETs or offsets, recalling that removals are far less beneficial than avoided emissions.

Also problematic is the fact that the *Strategic Assessment of Climate Change* opens the door for the use of NETs and other offsets, but, contrary to Principle #3, does not indicate that the environmental, social, cultural and other impacts associated with those NETs/offsets should be assessed as part of the review of these projects. Moreover, without clear and effective regulation of NETs, it is far from certain that they will offer actual and permanent removals of CO_2 (Principle #2).

Clearly Canada's laws need a major regulatory overhaul before NETs can be even considered as a tool in achieving its net-zero goals.

4.4 Who should pay for (and own) NETs in Canada?

As set out in Principle #4, Canada should look to international best practices and require the full cost of NETs to be borne by polluters, with a focus on atmospheric restoration and a very limited use of NETs to compensate for essential and extremely difficult to decarbonize emissions sources (Principle #1). However, there has been relatively little discussion in Canada of how NETs might be funded, or who will ultimately own the infrastructure, and for what purpose.

It is possible that public funding of private NETs projects will be provided, as has been done with CCS. Shell Canada's Energy Quest Project, for example, remains the most prominent example of an industrial CCS project in Canada, and it was built with $865 million from the Alberta and Canadian governments, representing 66% of the overall cost of the project.[98] Shell Canada claims that increasing the carbon tax to $170/tonne by 2030 and other existing policies will provide sufficient incentive for it to build a second Canadian CCS facility without any further subsidies.[99]

Nonetheless, there are clearly discussions about further subsidies. While Canada has a proposed a tax credit for CCS, the Canadian Association of Petroleum Producers has asked the Government of Canada to increase it substantially to pay for 75% of future CCS.[100] Furthermore, the Canadian government is apparently planning to "provide incentives" to encourage industry to build two massive "carbon storage hubs" by 2030.[101]

While carbon storage infrastructure will be necessary to store the CO_2 captured through DAC and BECCS, it is unclear that massive public investment in CCS technology is the best way to achieve this. Moreover, despite the considerable public dollars in play, it does not appear that the government is retaining any control over the resulting technology or facilities, including the ability to ensure that that they are eventually used to support NETs usage in accordance with Principle #1.

4.5 Recommendations to Canada on how NETs could be used to help Canada meet its climate targets

Canada needs clear rules outlining how NETs will be used to help Canada meet its international and domestic climate goals. Applying the same set of general principles identified in section 3.6, we recommend:

Principle #1 – Because of the risks, limitations and uncertainties, use NETs only for atmospheric restoration (reversing historic emissions) and to compensate for emissions deemed essential and extremely difficult to decarbonize.

- Amend the CNZEAA and other laws to limit the role of NETs in achieving Canada's emissions targets to compensating for historical emissions and addressing emissions from sources deemed essential and extremely difficult to decarbonize.
- Conduct a transparent assessment of essential processes for which decarbonization is extremely difficult and for which NETs and other CDR may be required to meet a net-zero target.
- To ensure that Canada is doing its "fair share" with respect to global responsibility, the government should move forward the date by which net zero will be achieved to well before 2050, and commit to negative emissions targets thereafter.
- Explicitly reject the use of NETs as a way to create space for continued fossil fuel use, and make plans for a swift phase-out of fossil fuels, while ensuring that workers and communities dependent on fossil fuels are supported.

Principle #2 – Ensure that NETs result in actual and permanent removals of CO_2 from the global atmosphere, resulting in net negative emissions.

- Develop stringent rules for NET projects that ensure that projects result in actual and permanent CO_2 removal.
- Ensure that the *Impact Assessment Act* and regulations and the *Strategic Assessment on Climate Change* require that a project's emissions must be consistent with a path to net zero; and for essential, hard to decarbonize sources of emissions, demonstrate that any NETs will permanently sequester the captured CO_2.

Principle #3 – Consider and manage the land, environmental, energy, social and cultural impacts of NETs.

- Ensure that rules regulating NET projects minimize environmental, social and cultural impacts.
- Fully and meaningfully involve Indigenous nations in NET projects occurring in their territory to ensure that such projects do not violate their rights.
- Ensure that the *Impact Assessment Act* and regulations and the *Strategic Assessment on Climate Change* stipulate that the full impacts of NETs will be reviewed in assessments.

Principle #4 – Ensure that polluters pay for the limited NETs that are needed.

- Ensure that any public subsidies or incentives for the development of NETs provide guarantees that storage capacity will be available and prioritized for extremely difficult to decarbonize functions, atmospheric restoration, and other public interest needs.
- Raise funding for NETs through a tax on polluting industries corresponding to the greenhouse gas emissions resulting from their products and operations.

V. Conclusion

NETs bring with them a slew of risks and limitations, uncertainties and ethical questions. Yet given the 1.5 °C imperative, and in view of IPCC modelling that indicates a need to use some NETs to reach net zero by 2050, NETs cannot be dismissed altogether. It is extremely important, however, that NETs are used only to compensate for essential and extremely difficult to decarbonize emissions and to draw down historical emissions, and that NETs are not used as an excuse to delay the drastic emissions reductions that are necessary to reach net zero.

If and when NETs are used (for the limited purpose stated above), government regulation will be required to ensure that, among other things: full life-cycle assessments of NETs are conducted to assess their efficacy in reducing atmospheric concentrations of CO_2; transparent monitoring, reporting and verification is in place to provide accurate accounting; and careful consideration of land, energy and water use is undertaken to inform siting and avoid negative environmental and social impacts. Further work is needed to determine the optimal way to fund NETs in a way that is most beneficial to the climate and public interest.

List of Acronyms

BECCS - Bioenergy Carbon Capture and Storage

CCS - Carbon Capture and Storage

CCU - Carbon Capture and Utilization

CCUS - Carbon Capture, Utilization and Storage

CDR - Carbon Dioxide Removal

CNZEAA- Canadian Net-Zero Emissions Accountability Act

CO_2 - Carbon dioxide

DAC - Direct Air Capture

GHG - Greenhouse gases

$GtCO_2$/yr - Gigatonnes of carbon dioxide per year

IEA - International Energy Association

IPCC - Intergovernmental Panel on Climate Change

NETs - Negative Emissions Technologies

WCEL - West Coast Environmental Law

Endnotes

1 Canadian Net-Zero Emissions Accountability Act, S.C. 2021, c. 22. Online https://laws-lois.justice.gc.ca/eng/acts/C-19.3/FullText.html

2 Ibid, s. 2.

3 Canadian Institute for Climate Choices. Canada's Net Zero Future. (2021). https://climatechoices.ca/wp-content/uploads/2021/02/Canadas-Net-Zero-Future_FINAL-2.pdf

4 Ibid p. 92.

5 Canadian Association of Petroleum Producers, "CAPP Statement: Canadian Net-Zero Emissions Accountability Act", Nov 19, 2020, online: https://www.capp.ca/news-releases/capp-statement-canadian-net-zero-emissions-accountability-act/. That quote goes on to say "such as carbon capture, use and storage." As noted below, CCUS is not accurately described as a Negative Emissions Technology, since it typically removes CO_2 from an industrial process, and at its theoretical best could only reduce those emissions rather than actually removing CO_2 from the atmosphere.

6 CICC Report, above, note 3, p. 104.

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