The problem of "Overshoot":
a framework for an honest public discussion about climate change and Canada's future oil production

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January 3, 2025

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Background

In May 2021 the International Energy Agency (IEA) published a pathbreaking report that examined the cuts in global oil, gas, and coal production that would be required by 2030, 2040, and 2050 to give us any realistic chance to limit the rise in the earth's average surface temperature to 1.5°C. The IEA's analysis concluded that, to meet that goal, a 23% reduction of global oil production will be required by 2030, a 50% cut by 2040, and 75% cut by 2050. The IEA warned that based on the current policies of the world's top oil, gas, and coal producers (including Canada) we are on track to see warming of 2.4°C by 2100.

Following the release of the IEA's report in May 2021 there were public calls from leading climate scientists and energy economists in Canada urging that the Federal Government's energy agency, the Canada Energy Regulator (CER), should conduct its own analysis to determine what future levels of oil production in Canada would be consistent with meeting the1.5°C goal.

On June 20, 2023, the CER published a report called *Canada's Energy Future 2023*. The document is important because for the first time Canada's national energy agency has directly addressed the impacts on our oil production if global oil levels are aligned with the 1.5°C goal. The CER's new report accepts the accuracy of the IEA's findings and has acknowledged that meeting that goal would require a 50% reduction of Canada's oil production by 2040.

Yet, despite these highly consequential findings, during the past two or three years a series of very different ideas have begun to dominate the political discussion and government policymaking on the matter of oil and gas production. The new policy approach is that in order to keep amassing the wealth and economic benefits of maintaining high levels of oil production, any deep reductions in oil production (in Canada and globally) should be deferred for another 10 or 15 years, with the result that a significant amount of "overshoot" will occur (i.e., the rise in the earth's average surface temperature will exceed 1.5°C by some amount, rising to 1.7°C or well above that) but with the promise that, after 2050, Carbon Capture and Storage (CCS) and novel Carbon Dioxide Removal (CDR) technologies with the capacity to remove massive amounts of carbon dioxide from the atmosphere will allow our children and grandchildren to eventually lower those higher temperatures back down to about 1.5°C.

In line with this alternative approach, since about 2021 in Canada, the United States, and in the UK, governments have adopted new policy measures that provide subsidies to support the build-up of CCS technology at emissions-intensive industrial sites (including at oil sands production sites in Alberta). The political and industry argument in Canada is that large-scale adoption of Carbon Capture and Storage technology at oil and gas production and processing sites will enable us to achieve some reductions of our "upstream emissions" while allowing us to continue having the economic benefits of higher levels of production.

In 2023, the hottest year ever recorded, the earth's average surface temperature increase reached 1.48°C, measured against the pre-industrial baseline (average temperature for 1850-1900). However, climate scientists use a lower number, 1.2°C, as the official measure of long-term warming up to 2023, which is calculated by averaging temperatures over the past twenty or thirty years to eliminate short-term fluctuations between individual years. The 1.2°C figure also understates the warming now actually experienced by most people because it represents the

average surface temperature of the entire earth's surface including air temperature over the oceans, which are generally cooler than over the land surface, and over the Arctic and Antarctic. In actuality, warming and the impacts of warming vary enormously between different regions. Canada's Arctic and the entire north polar region has already warmed more than 3°C within the past 40 years. Across much of Canada's continental land mass, Central Asia, and South Asia, the increase in average surface temperature is already more than 2°C. These increases are being further elevated in the hot season and during heat waves to extreme levels, for example in April and May 2024 driving temperatures across the Philippines, Cambodia, Vietnam, Myanmar, Bangladesh, and Pakistan to record levels well above 40°C and to as much as 48°C and 49°C.

Therefore, although projected temperature increases of 1.5°C and 1.7°C might appear to be of limited significance, the actual impacts on human health and on natural systems are already severe. Deadly heat waves are already more frequent, more intense, and last longer even in temperate regions. The town of Lytton in south-central British Columbia reached 49.6°C on June 29, 2021, breaking the previous Canadian temperature record by an extraordinary 4.6°C. The town was consumed by wildfire the following day. This "heat dome" lingered for about seven days and accounted for 618 heat-related deaths in B.C. It also caused a massive kill of marine life in shallow tidal waters and salmon streams along B.C.'s Pacific Coast.

1. The IEA's "Net-Zero by 2050 Scenario"

The IEA's Net-Zero by 2050 Scenario ("NZE Scenario") was first published on May 18, 2021. It analyzed the needed reductions in oil, natural gas, and coal combustion emissions to 2050 that would be aligned with a 50-50 chance to limit the rise in global warming to 1.5°C. Updated versions of the NZE Scenario were published in October 2022 and in September 2023: https://iea.blob.core.windows.net/assets/9a698da4-4002-4e53-8ef3-631d8971bf84/NetZeroRoadmap_AGlobalPathwaytoKeepthe1.5CGoalinReach-2023Update.pdf. The IEA's report also includes two other scenarios which help us understand the implications of continuing to produce higher levels of fossil fuels through to 2040 and 2050.

1.1 Limiting the warming increase to 1.5°C:

The IEA's "NZE" Scenario concludes that to stay on a pathway to meet the 1.5°C goal a *23% reduction* in global oil production would be required by 2030 down to 77 million barrels per day (bpd), and that a 50% cut to 44 million bpd must be achieved by 2040. A further decline to 24 million by 2050 is needed to stay within the 1.5°C warming limit. In addition, to meet that goal 70% of the remaining 24 million bpd of production by 2050 will have to be used in applications where *the fuel is not combusted and so does not result in any direct CO_2 emissions* (i.e., used to produce chemical feedstocks, lubricants, and asphalt). By 2050, oil must have very limited use as a transportation fuel except for aviation.

1.2 The IEA's second (APS) scenario leads to 1.7°C:

The IEA's second scenario is called the "Announced Policies Scenario" (APS). The APS Scenario offers a much slower transition away from fossil fuels. It projects the path of global oil

production based on "promised" additional future policies and goals by multiple countries which, if fully implemented, would gradually reduce global oil consumption, but at a much slower pace. The APS scenario, if it is followed, leads to warming of 1.7°C by 2050, and even higher levels of warming to 1.8°C or above depending on whether, and when, promised future climate measures are implemented. The APS Scenario is highly speculative because it is based on promised future climate policies in other countries that have not yet even been developed or identified in any detail. In many cases they promise simply to reach "net-zero" emissions by 2050, but with no information about the measures they will adopt in future to meet that goal.

1.3 The IEA's third scenario (STEPS) leads to 2.4°C

The IEA's Stated Policies Scenario ("STEPS") projects the expected future path of oil demand over the next 30 years based on existing energy policies. The STEPS scenario counts the benefit of all promised new carbon-reduction measures that have already been adopted by governments and this scenario *assumes* all those measures will be fully implemented. STEPS reflects the pathway we are presently following. Under the STEPS Scenario global oil production continues to increase to 103 million bpd by 2030 and flatlines at that level to 2050. It aligns with 2°C warming by 2050 and 2.4°C by 2100.

2. The Canada Energy Regulator's report "Canada's Energy Future 2023"

On July 8, 2021, a group of twenty-one energy economists and climate scientists sent a letter to the Prime Minister. It cited in detail the findings of the IEA's May 18, 2021 "Net-Zero Emissions by 2050 Scenario" and was copied to the Minister of Natural Resources and others. They wrote: "Specifically, we urge you to mandate that the Canadian Energy Regulator model scenarios consistent with the IEA's Net Zero by 2050 report": i.e., instruct the CER to develop scenarios that will identify the much lower and declining oil production levels in Canada over the next 20 to 30 years that would be safely aligned with an effective global effort to stay within the 1.5°C warming threshold.

On December 16, 2021, Canada's Minister of Natural Resources, Jonathan Wilkinson, belatedly instructed the CER that it "undertake scenario analysis" relating to Canada's future oil production. After eighteen months, the CER's report was publicly released on June 20, 2023.

2.1 The CER's 1.5°C-aligned "Global Net-Zero Scenario"

The CER in its June 20, 2023 report provides details of what it calls its "Global Net-zero Scenario", a new scenario prepared by the CER which, the CER says, is modelled on the IEA's "Net-Zero by 2050 Scenario". The CER's new "Global Net-zero Scenario" if it were adopted to guide Federal and provincial policy in Canada relating to oil production would result in very rapid and deep reductions in Canada's oil production after 2030, falling almost by half by 2040. The oil production data shown in Figure A below is taken from the Data Appendices attached to the new CER report,

Figure A: *Canada's Energy Future 2023*: oil production scenarios: projections (in millions bpd)

	2019	2022	2027	2030	2040	2050
Global Net-zero Scenario (NZE)	4.889	5.146	5.741	5.592	2.866	1.284
Canada Net-zero Scenario (APS)	4.889	5.146	5.896	6.060	5.197	4.081
Current Measures Scenario	4.889	5.146	5.981	6.286	6.496	6.260

Source: *Canada's Energy Future 2023*, Data Appendices
(https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA)

Under the CER's "Global Net-zero Scenario" (stated to be aligned with the IEA's Net-Zero by 2050 Scenario) Canada's oil production peaks at 5.7 million bpd by 2027 and thereafter declines sharply to 2.866 million bpd by 2040 (a 50% reduction in the next decade) and falls to 1.284 million bpd by 2050.

The CER 2023 Report has accepted that in a world that aims to limit the increase in the earth's average surface temperature to 1.5°C, Canada's oil production (and overall global oil production) will have to decline about 50% by 2040 below the 2027 level – and decline about 75% by 2050.

2.2 The CER's second scenario: the "Canada Net-Zero Scenario"

The CER's second scenario is called the "*Canada* Net-zero Scenario", which the CER claims is modelled on the IEA's Announced Policies Scenario. The APS Scenario envisions a much slower transition away from oil, natural gas, and coal. The APS models future levels of global oil production on the assumption that countries continue to follow their *currently existing policies* (which offer no early decline in oil and gas use) but it also counts the benefit of multiple "pledges" by countries to reduce their emissions in future (e.g., a promise by India to reach "net-zero" by 2070) including bare promises by many countries to take action many years in the future, promises that have no basis at all in any developed or existing plans.

In the case of the APS Scenario, the assumption is that all countries will continue to produce comparatively high levels of oil, natural gas, and coal for another 15 years or longer, but that as we approach 2040 and after they will begin to gradually adopt more stringent climate policies which, by 2100, will achieve "net-zero".

Under this "Canada Net-zero Scenario" (based on the IEA's APS modelling), global oil use remains at much higher levels to 2040 and then begins a gradual decline. In this scenario Canada's oil production grows from 5.146 million bpd in 2022 to 6.060 million bpd by 2030, and then slowly declines to 5.197 million by 2040 (which represents no reduction at all below the 2022 level). Production falls to 4.081 million bpd by 2050, which is only about 20% below the 2022 level.

The CER's Canada Net-Zero Scenario is based on this assumption of 'delayed' action. Under this APS-aligned scenario, however, it is a mere conjecture that all of those promised future

actions over the next 50 years that are counted in the APS scenario will ever actually be implemented, and that they will be effective. Nevertheless, the IEA concludes in its APS Scenario that, on the *assumption* all those promises of future action by dozens of countries are fully implemented, the world could reach "net-zero" by 2100.

Those escalated levels of annual global emissions (driven by sustained high levels of oil and natural gas and coal use between 2030 and 2050) will drive the earth's average surface temperature rise to about 1.7°C or 1.8°C by 2050 and during the following decades.

2.3 The CER's third scenario: "Current Measures Scenario"

The CER's third scenario is a "business as usual" scenario – but useful for purposes of understanding where we are presently headed. It assumes that Canada's oil production will continue to expand for more than another 20 years, and that by 2050 it will be 6.2 million bpd, still 20% above the 2022 level. The CER report does not disclose any information about the impacts on the earth's climate system if oil production continues to rise in line with that scenario. It is clear, however, that the CER's third scenario is broadly aligned with the IEA's STEPS Scenario, which projects warming of 2°C by 2050 and 2.4°C by 2100.

3. The remaining carbon budget to stay within the 1.5°C warming limit

We know, based on the most recent reports from the IPCC and other sources, that the remaining global carbon budget to keep the rise in the earth's average surface temperature to less than 1.5°C is only about 275 billion tonnes (Gt) of carbon dioxide. Global emissions from combustion of oil, natural gas, and coal reached an annual level of 37 $GtCO_2$ in 2022. If we continue following the current pathway, the entire remaining carbon budget for 1.5°C will be exhausted within six more years. Recent sources addressing the magnitude of the remaining carbon budget to 1.5°C include the following:

The report of Working Group 1 to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (released in August 2021) provided an updated assessment of the remaining carbon budget. The findings summarized in the Summary for Policy Makers at Table SPM.2 show that the remaining carbon budget with a 67% likelihood of limiting warming to 1.5°C is 400 $GtCO_2$. This 400 $GtCO_2$ number was calculated as of January 2020 and therefore must be reduced to account for four more years of ongoing emissions since that time, at the rate of approximately 40 $GtCO_2$ every year. Recent carbon budget studies undertaken in 2023 calculate that the remaining carbon budget, from the beginning of 2024, is now 275 $GtCO_2$. "Remaining Carbon budget 2023", Copernicus, December 5, 2023, gives the remaining carbon budget with a 50% likelihood to limit global warming to 1.5°C as 275 $GtCO_2$, from the beginning of 2024: https://essd.copernicus.org/articles/15/5301/2023/.

Therefore, after 2030 (or possibly as early as 2028) all additional CO_2 emissions generated by the ongoing combustion of fossil fuels will directly contribute to driving warming above 1.5°C unless (1) they are "captured" before they are released into the atmosphere by CCS technology and securely sequestered underground, so they never reach the atmosphere, or unless (2) they can eventually be removed from the atmosphere by carbon removal technologies (CDR) which do

not yet exist in any viable or scalable form. We are now six years away from exceeding the upper limit on the amount of CO_2 that can be released into the atmosphere that is compatible with limiting the warming increase to 1.5°C.

4. Global emissions implications of following the "Canada Net-Zero Scenario"

There is no detailed information contained in the CER's report about how much higher global emissions from oil, gas, and coal combustion will be under its "Canada Net-Zero Scenario" (which is modelled on the IEA's APS Scenario) compared to a scenario that limits warming to 1.5°C. For that kind of information, we must go to the *IEA World Energy Outlook 2023* report (October 2023). It provides full details of the projected annual level of global emissions over the period up to 2050 under each of its three scenarios:

Figure B: Annual global fossil fuel emissions by Scenario: billions of tonnes of CO_2 ($GtCO_2$)

	2022	2030	2035	2040	2050
Net-Zero by 2050 Scenario (NZE)	36.9	24.0	13.3	6.4	-
Announced Pledges Scenario (APS)	36.9	30.7	24.2	19.2	12.0
Stated Policies Scenario (STEPS)	36.9	35.1	33.0	31.6	29.6

Source: *World Energy Outlook 2023*, October 2023, World CO_2 emissions, Tables A.4a, A.4b, and A.4c at pages 268, 274, and 280.

4.1 Global emission in the case of the IEA's 1.5°C-aligned scenario

Global emissions from combustion of fossil fuels reached an annual level of 36.9 billion tonnes ($GtCO_2$) in 2022. In the case of the IEA's 1.5°C-aligned scenario, the top line in Figure B shows the very sharp decline in annual emissions from fossil fuel use required by 2040 and 2050. Under the NZE Scenario, the projected *cumulative* volume of additional emissions from oil, gas, and coal combustion is approximately 400 $GtCO_2$ by 2050. Fossil fuel emissions are reduced to net-zero by 2050 (i.e., the promise is that thereafter any "residual" or remaining emissions will be "balanced' in subsequent years by CCS or direct air removal technologies).

However, the remaining carbon budget is only 275 Gt (see Part 3 above). In the case of the NZE scenario the cumulative emissions by 2050 will exceed the remaining carbon budget by approximately 125 $GtCO_2$. According to the IEA's analysis, that excess amount will bring a "temporary" warming increase to 1.6°C by 2050. In this most ambitious scenario, which assumes a rapid 50% decline in oil production by 2040 and a 75% cut by 2050, some amount of "overshoot" is now unavoidable.

The IEA's report *Net-Zero Roadmap: A Global Pathway to Keep the 1.5°C Goal in Reach* (September 26, 2023) at page 63 explains how it is possible for a "limited overshoot" to 1.6°C to

be reduced to 1.4°C by 2100. The cumulative amount of atmospheric carbon that exceeds the 1.5°C warming threshold is relatively limited. Large-scale carbon dioxide removal by CDR technologies is not required. Instead, the temperature reduction is caused by two effects that do not depend on CDR. One is strong reductions in methane emissions to 2050. Unlike carbon dioxide, methane dissipates from the atmosphere over a relatively short period of time. The IEA's NZE Scenario assumes that new policy measures will accelerate large reductions in methane emissions before 2050, which will result in a marked decline in the warming effect of methane over the following decades. That ambitious effort to cut methane emissions accounts for 0.1°C of cooling between 2040 – 2100. The second effect is that temperatures are reduced as the land and oceans begin to draw down atmospheric carbon after 2050. Once human activity stops releasing more CO_2 into the atmosphere, absorption of atmospheric carbon into the oceans and biological uptake into forests and plants (which can only occur very slowly over decades and centuries) accounts for the other 0.1°C of cooling between 2050 and 2100.

4.2 Cumulative emissions to 2050 under the IEA's STEPS Scenario

In contrast, in the case of the IEA's STEPS Scenario the cumulative volume of additional emissions by 2050 will be approximately 900 $GtCO_2$, far exceeding the remaining global carbon budget. That scenario, which is based on a detailed appraisal by the IEA of the actual energy plans and existing climate measures already implemented or under development in all countries, results in a warming increase of 2°C by 2050. Further, after 2050, that cumulative amount will continue to increase by another 20 to 30 $GtCO_2$ or so every year (with the amount of the annual increases gradually falling when, and if, production levels decline) for another 30 or 40 years, or longer, until global fossil fuel consumption may belatedly be reduced to lower levels. On that basis, cumulative emissions will continue to rapidly increase, exceeding about 1200 $GtCO_2$ as early as 2060 and rising further every decade after that. If major oil and gas producing states choose to follow the STEPS Scenario, warming by 2100 will reach 2.4°C.

In a more recent report published on November 23, 2023, entitled *The Oil and Gas Industry in Net-Zero Transitions* the IEA warned that deploying CCS and future CDR technologies on a sufficient scale to rectify that kind of massive overshoot is "inconceivable":

> *If oil and natural gas consumption were to evolve as projected under today's policy settings (i.e., as shown in the IEA's STEPS Scenario), this would require an inconceivable 32 billion tonnes of carbon captured for utilization or storage by 2050, including 23 billion via direct air capture to limit the rise to 1.5°C.*
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> — IEA *Oil and Gas Industries in Net-Zero Transitions*, November 2023, p. 15

4.3 Cumulative emissions to 2050 under the IEA's APS Scenario

The middle pathway described in the IEA's APS Scenario, which delays any deep cuts in oil and gas production until we approach 2040, results in additional cumulative emissions of approximately 650 $GtCO_2$ by 2050. Furthermore, under the APS Scenario, substantial emissions from ongoing oil, gas and coal production will continue albeit at gradually declining levels through to 2100. That ongoing reliance of fossil fuel energy after 2050 will generate another

approximate 250 $GtCO_2$, or possibly much more, depending on the exact rate of decline after 2050. Therefore, the APS Scenario (which provides the model for CER's own "Canada Net-Zero Scenario") offers a plan that will result in an additional approximate 900 $GtCO_2$ of cumulative carbon dioxide emissions between now and 2100 – which represents about 650 $GtCO_2$ of additional CO_2 released into the atmosphere over and above the remaining carbon budget for 1.5°C.

It is the rising atmospheric carbon concentration that is driving the warming of the earth's surface. The question of the feasibility of large-scale future carbon removals has therefore become central to our predicament.

5. Carbon Capture and Storage

Governments (including Canada) promise that Carbon Capture and Storage technology (CCS) over the next 20 to 30 years will allow us to capture CO_2 at large emissions sites such as coal and natural gas-fired electricity plants *before it is released into the atmosphere* and safely secure it in deep underground storage. That, we are told, will allow higher levels of fossil fuel burning to continue for decades to come.

However, the available evidence is clear that no plausible future scale of CCS installations worldwide could ever offset a significant share of the projected levels of annual emissions generated by currently projected high levels of oil, gas, and coal combustion. The current annual emissions level is 37 $GtCO_2$ every year: see Figure B above. Even by 2040, the projected annual level remains above 30 $GtCO_2$ under the STEPS Scenario, and just under 20 $GtCO_2$ per year under the more moderate APS Scenario.

The *World Energy Outlook 2023* report (October 24, 2023) provides the IEA's estimate of the feasible build-up of global CCS capacity by 2050. The IEA's estimate is that by 2050 global CCS capacity could reach as much as 6 billion tonnes ($GtCO_2$) per year. And the build-up to even that relatively small global capacity is expected to be very gradual. The amount captured by 2030 is estimated at 1.0 $GtCO_2$, rising to 3.7 Gt by 2040.

The IEA's report *Net-Zero Roadmap: A Global Pathway to Keep the 1.5°C Goal in Reach* (September 26, 2023) examines the number of CCS projects currently operating worldwide or under construction, as well as those at the "advanced development stage" and at the "concept and feasibility" stage. This analysis finds that "if all the CO_2 capture projects in the pipeline are realized, CO_2 capture capacity would rising from 45 million tonnes (Mt) today to reach nearly 400 Mt per year in 2030" (page 39). That 400 Mt amount is equivalent to about 1% of current global fossil fuel emissions. The result is that between now and 2050 most of the ongoing emissions from oil, gas, and coal combustion will continue to be released directly into the atmosphere.

Assuming a scale-up of CCS capacity to 6 $GtCO_2$ is fully achieved by 2050, the cumulative amount of CO_2 that will be "captured" over the next 26 years will be about 70 $GtCO_2$ in total. Yet, in the case of the IEA's APS Scenario where globally we delay any deep cuts in fossil fuel production for several more decades (which provides the modelling framework for Canada Net-

Zero Scenario), between now and 2050 fossil fuel combustion will account for additional cumulative emissions of 650 $GtCO_2$. Even with a successful build-up of some CSS capacity in the order of 6 Gt per year by 2050, most fossil fuel combustion emissions will continue to be released directly into the atmosphere. In the case of the STEPS Scenario, the volume of cumulative CO_2 released by 2050 from the ongoing combustion of oil, gas, and coal will be in the order of 900 $GtCO_2$ (about 650 Gt of that will exceed the remaining carbon budget). The promised build-up of CCS capacity can address only a fraction of the problem.

6. Carbon Dioxide Removal

"Overshoot" is a term that describes an increase in average global surface temperature above 1.5°C. A "high overshoot" refers to an increase above 1.6° but not exceeding 1.8°. It is now unavoidable that some amount of overshoot is going to occur. Once that has occurred, and if we seek to ever bring temperatures back down to a safe level, the only solution will rest on future development of Carbon Dioxide Removal (CDR) technologies.

6.1 Carbon dioxide removal required to achieve a 0.1°C reduction

Once warming exceeds 1.5°C, rising for example to 1.7°C or above, the scale of the emissions "removals" that would be required in future to roll us back to a more survivable level of warming using envisioned CDR technologies is enormous:

> *Obtaining net-negative CO_2 emissions requires massive deployment of carbon dioxide removal (CDR) in the second half of the century, on the order of 220 (160-370) $GtCO_2$ for each 0.1°C degree of cooling (based on the assessment of the likely range of the transient response to cumulative CO_2 emissions …*
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> — IPCC AR6 Working Group III, Chapter 3 section 3.5.2.1 (emphasis added)

To roll back warming by just 0.1°C we would need to "remove" from the atmosphere about 220 $GtCO_2$, which at current rates of burning coal, oil, and natural gas is equivalent to about five years' worth of accumulated emissions. Assuming some carbon removal technologies are feasible and are available by 2050, rectifying even just 0.1°C degree of overshoot would require about 5 Gt of carbon removal per year over the 50 years between 2050 and 2100.

6.2 Types of carbon removal technology

The required CDR technologies do not yet exist or exist only in very small-scale experimental forms. We have no assurance that these schemes will be viable on the vast scale envisioned. The capability and purpose of the promised CDR technologies is fundamentally different than CCS. CCS captures CO_2 at emitting facilities, before it is released into the atmosphere. In contrast, CDR has the capability to remove CO_2 from the atmosphere after it has been released.

One prominent CDR scheme, called Bioenergy with Carbon Capture and Storage (BECCS), envisions that we will grow crops on a massive scale that will absorb CO_2 from the air in the growing season. These crops will then be harvested and burned, and through that combustion

process the CO_2 embedded in the plants will be released and captured by CCS, then compressed and injected underground for permanent storage.

Other proposed CDR technologies, still at the concept or early development stage, envision chemical processes and materials that would directly absorb CO_2 out of the air (direct air capture combined with CCS, referred to as "DACCS"). There are experimental prototypes of some of these ideas. Huge unanswered questions remain about the viability of scaling up these schemes, economic costs, and high levels of energy use.

6.3 Feasible levels of Carbon Dioxide Removal (CDR) capacity by 2050

The IEA estimates that, by 2050, we may have developed global capacity to remove about 1.7 $GtCO_2$ from the atmosphere per year – a relatively small amount compared to the annual level of emissions from the current high level of annual fossil fuel emissions (37 $GtCO_2$). Of that estimated 1.7 $GtCO_2$ amount, about one-third will be by DACCS and the balance by BECCS**.** In its report published on November 23, 2023, the IEA gives this explicit caution that assuming much higher levels of future carbon removals, over and above 1.7 Gt, is unrealistic:

> *CO_2 removal via DAC is not an unlimited resource, and the level of DAC in the NZE Scenario is likely to be close to the upper bound of what is practicable by 2050.*
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> — IEA, *The Oil and Gas Industry in Net-Zero Transitions*, page 94 (emphasis added)

The IEA explains in its report *A Net-Zero Roadmap: A Global Pathway to Keep the 1.5°C Goal in Reach* released on September 26, 2023, that with even a relatively limited amount of "overshoot", for example if warming reaches 1.7°C, an effort to roll back that higher level of temperature by even 0.1°C or 0.2°C would require that we (our children and grand-children) rely on CDR technologies to remove over 5 $GtCO_2$ every year during the second half of this century, seeking to achieve total removals of about 250 $GtCO_2$ by 2100: see IEA, *A Global Pathway to Keep the 1.5°C Goal in Reach*, section 3.3.3. at p. 153.

The massive scale of the needed BECCS infrastructure would require allocating a substantial share of the world's available croplands (and water resources) to grow sufficient biomass material to be burned in these future facilities to extract their CO_2 – which will compete with demand for land and water to support global food supply. We are already seeing worsening drought conditions and escalated temperatures that are adversely affecting crop yields.

The recent *Production Gap 2023* report prepared by the Stockholm Environmental Institute, Climate Analytics, E3G, International Institute for Sustainable Development (IISD), and the United Nations Environmental Program also takes a hard look at the *feasibility* of achieving these higher levels of carbon removal by BECCS and DACCS. Based on studies that have assessed the "feasible potential" of carbon removal technologies, the *Production Gap* report finds that carbon removals relying on these "novel" technologies could reach 3.0 $GtCO_2$ per year by 2050 (moderately higher than the IEA's 1.7 $GtCO_2$ estimate).

While acknowledging that its 3.0 $GtCO_2$ estimate lies within the range of "feasibility potential", the *Production Gap* report nevertheless concludes that it remains "highly uncertain whether the

new technology will become viable at scale" and capable of achieving even that modest level of removals described as feasible.

7. Afforestation: the limits of nature-based solutions

Nature-based methods of carbon removal include planting new forests, the reforestation of previously deforested areas (referred to as A/R), wetland restoration, soil carbon sequestration, and other strategies aimed at preserving and enhancing carbon storage in ecosystems and on agricultural lands. But when compared to the massive scale of the amounts of carbon dioxide released into the atmosphere every year by combustion of oil, natural gas, and coal (in 2023 the amount was 37 billion tonnes), the potential we have for offsetting even a small share of those annual increases by enhanced carbon sequestration in natural ecosystem is very limited.

The *Production Gap* report estimates that removal of 2.2 $GtCO_2$ per year may be feasible by these nature-based methods of increasing sequestration. The IEA's *Direct Air Removal* report (June 2023) gives a range of 0.5 to 5.0 $GtCO_2$ per year. However, it is broadly acknowledged that a major uncertainty underlying heavy reliance on nature-based solutions is the "impermanence" of methods that aim to preserve and enhance storage in terrestrial or aquatic ecosystems. The risk is that successfully stored land carbon could be subsequently lost back to the atmosphere as a result of future disturbances such as wildfires and deforestation. A recent paper by climate scientists Damon Matthews and Kirsten Zickfeld, published on March 17, 2022, points out that portraying nature-based mitigation activities as equivalent to and interchangeable with fossil fuel CO_2 emissions reductions rests on the implicit assumption that the "removed carbon" will be permanently sequestered:

> *This is a critical assumption that has not been well acknowledged in the literature to date; indeed, anything less than permanent storage would result in only a temporary climate benefit that would not match the multi-century to millennial-scale warming caused by fossil fuel CO_2 emissions. However, the permanence of carbon storage in natural ecosystems cannot in reality be guaranteed, given its vulnerability to both human-driven (e.g., deforestation or other land-use change) and climate-related (e.g., wildfire, drought, or insect) disturbances that could occur at any time in the foreseeable or unforeseeable future.*
>
> — D. Matthews and K. Zickfeld, et al., "Temporary nature-based carbon-removal can lower peak warming in a well-below 2°C scenario", *Communications Earth & Environment* (2022) 3:65, p. 4.

The authors of this paper warn that we should assume that *some or all this carbon storage* by nature-based solutions will be temporary and then ask: to what extent will temporary carbon sequestration contribute to meeting our goal of halting the earth's rising surface temperature? Their study is based on an estimate that removals by nature-based methods could reach a maximum removal rate of 3.64 to 10.4 $GtCO_2$ per year. They conclude that removals on that scale, even if temporary, can reduce "peak" warming by 0.04°C to as much as 0.17°C during the critical years between 2040 and 2060. That is a critical period because, as we approach 2050 and if we are by then in the final stages of successfully achieving very deep reductions in oil, gas, and coal production (but have not quite reached net-zero emissions), the cumulative level of CO_2

in the atmosphere will still be rising and during that decade be reaching its highest point ever. Some amount of temporary "overshoot" above 1.5°C is unavoidable. Climate scientists have warned that every 0.1°C of warming above 1.5°C will bring irrevocable loss and destruction to natural systems. A reduction of peak warming by even $1/10^{th}$ of a degree will be significant.

However, if high levels of carbon emissions from fossil fuel combustion continue to 2040 and beyond, the promised benefit of nature-based carbon removals will be completely lost. The relatively modest scale of removals by A/R in that situation will be very quickly overcome by the continuing release of higher levels of CO_2 from oil, gas, and coal burning. The only benefit of nature-based carbon removal in that case will be to slightly delay the onset of higher surface temperatures. According to the study by Matthews and Zickfeld, reaching the 1.5°C warming level will occur about one year later and we will pass the 2°C threshold about 2 to 8 years later.

Also see the Council of Canadian Academies (CCA), *Expert Panel on Canada's Carbon Sink Potential*, December 2022: https://cca-reports.ca/wp-content/uploads/2022/12/Carbon-Sinks_EN_Final.pdf. This report by a panel of fifteen experts examines the prospects for enhancing carbon storage and reducing emissions in Canada's forests, wetlands, grasslands, agricultural lands, and costal zones. It estimates that the overall cost-effective mitigation potential (i.e., carbon sequestration or emissions reductions) could in Canada reach approximately 40 Mt CO_2e per year by 2030, which the Panel notes is equivalent to about 6% of Canada's current annual emissions.

However, the CCA report addresses the high level of uncertainty about the attainable future level of removals by these proposed nature-based climate solutions ("NBCSs"). It also warns of the risk of very large-scale emissions releases from Canada's vast landscape, driven by rising temperatures, wildfires, and deforestation: "the global climate risks of increasing (and accelerating) emissions from Canada's terrestrial, aquatic, and coastal ecosystems are substantial – in contrast to the more modest benefits of NBSCs" (Section 7.4, page 184). Large-scale emissions releases could offset any reductions achieved by proposed nature-based solutions. That warning was given in 2022.

During 2023, wildfires on an unprecedented scale across Canada released 1.7 billion (Gt) tonnes of CO_2 into the atmosphere, representing 25% of total global wildfire emissions for 2023: https://atmosphere.copernicus.eu/2023-year-intense-global-wildfire-activity. That single fire season release in Canada was equivalent to (and would completely offset) about 40 years of future carbon removals by NBCSs in Canada at the projected rate of 40 Mt CO_2 per year.

8. Canada's declared policy: leaving it to oil producers to choose a safe pathway

The Federal Government's official document published on March 29, 2022, the *Emissions Reduction Plan 2030* (ERP), confirms that none of the government's proposed new climate policies, including plans to subsidize large-scale deployment of Carbon Capture and Storage (CCS) technology in the oil sands industry, are intended to bring about any decline in the currently projected growth of Canada's oil production. Indeed, the text of the ERP affirms that the aim of government policy will be to continue to maximize production:

> *The government will work closely with the provinces and the sector to manage competitiveness challenges, remain attuned to evolving energy security and climate risk considerations, maximize opportunities for ongoing investment in the sector, and minimize the risk of carbon leakage. The intent of the cap is not to bring reductions in production that are not driven by declines in global demand. Mechanisms like the CCUS investment tax credit will help support decarbonization.*
>
> — *2030 Emissions Reduction Plan*, March 29, 2022, p.53 (emphasis added)

The government's policy is clear: Canada's oil production will continue to increase until – and if – other countries eventually begin to consume less oil. In the meantime, Canada's production levels will be guided solely by "global demand".

9. Why 2030 is an unforgiving deadline to achieve deep cuts in oil production

The *UN Emissions Gap 2022 Report* published October 27, 2022, provides a comprehensive picture explaining the extreme danger of our situation. It includes three crucial findings that define the scale of the problem. The annual level of global GHG emissions, not including emissions from changes in land use (i.e., land use change including deforestation), reached an estimated 52.8 $GtCO_2eq$ in 2021.

The first crucial finding is that with the benefit of all emissions reduction policies currently in place (that means all policies that have already been implemented by all countries and assuming that no additional action is taken) global emissions are projected to increase to 58 $GtCO_2eq$ by 2030. That emissions pathway (the "Current policies scenario") will result in warming of 2.8°C during the twenty-first century. That is the pathway we are presently on.

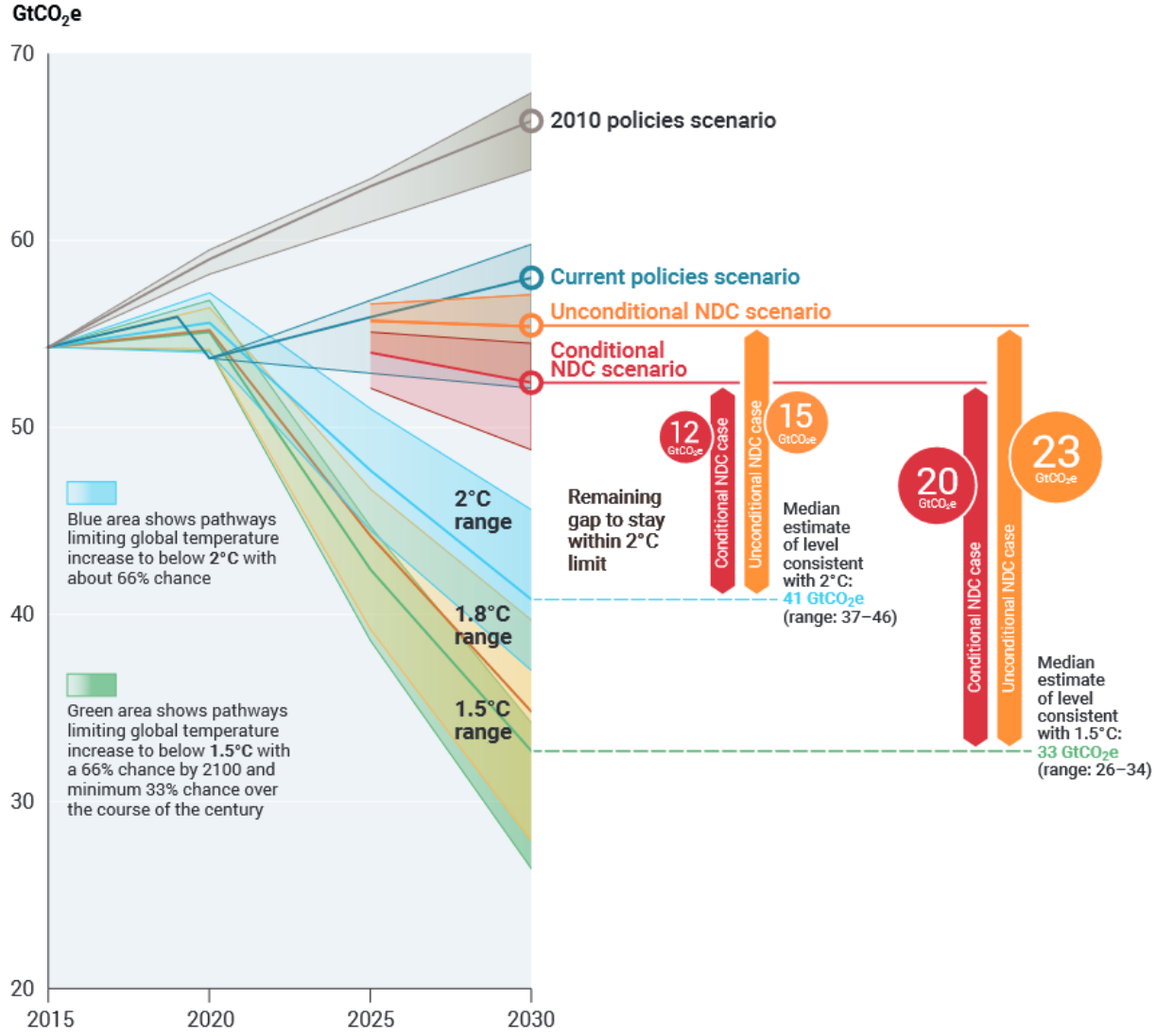
Second, even with the full implementation of all unconditional NDCs (emissions reduction commitments made by individual countries under the 2015 Paris Agreement, referred to as 'Nationally Determined Contributions'), global emissions are on track to reach 55 $GtCO_2eq$ by 2030. The annual level of global emissions by 2030 will still be higher than it was in 2019, even if all the NDCs promised so far are fully achieved. That level of global emissions by 2030 will put us on a pathway to a temperature increase of 2.6°C above pre-industrial levels. That outcome is depicted by the orange line (the "Unconditional NDC scenario") shown in Figure C below.

A third crucial finding set out in the *UN Emissions Gap 2022* report is that to stay on a pathway to limit the warming increase to 1.5°C, global emissions must decline to an annual level of 33 $GtCO_2eq$ between now and 2030 (far below the projected 55 $GtCO_2eq$, which assumes all the unconditional NDCs so far promised will be fully implemented). That means we must achieve additional reductions of 23 $GtCO_2eq$ by 2030. That is referred to as the "emissions gap" to 1.5°C. Closing the emissions gap would require achieving a 45% reduction of all emissions world-wide within the next six years.

Canada promises to reduce our domestic emissions 40% by 2030, below the 2005 level. That is our NDC. But even if Canada and all other countries successfully implement and achieve the full

amount of their promised unconditional NDC reductions by 2030, that still leaves us on a path to a temperature increase of 2.6°C above pre-industrial levels.

Figure C: Global greenhouse gas emissions scenario and the emissions gap to 2030



Source: UN Emissions Gap Report 2022, October 27, 2022, Figure ES.3

Of the total amount of greenhouse gas emissions which reached an estimated 52.8 $GtCO_2eq$ in 2021, about 70% of that amount were emissions from burning coal, oil, and natural gas – representing about 37 $GtCO_2$.

CO_2 emissions from coal, oil, and natural gas use must be reduced by more than one-third within the next six years – falling from 36.9 to 24 $GtCO_2$ by 2030: see *World Energy Outlook 2023*: see the emissions data tables summarized in Table B above. Oil use at present continues to increase. Coal use has been slowly declining in the richest advanced industrial economies, but natural gas use is rising. Achieving a reduction in overall global emissions cannot be achieved without deep

cuts in oil production, along with equivalent cuts in coal and natural gas, all within the next six years.

The CER in its recent *Canada's Energy Future 2023* report is completely silent about the "emissions gap" and why it must be closed within the next six years.

10. Another warning: the rising atmospheric carbon concentration level

The *atmospheric carbon concentration level* is the metric that explains why the timeline to arrest the further expansion of all fossil fuel production – and to achieve deep cuts in our overall consumption of oil, coal, and natural gas – is brief and unforgiving. It records the rising concentration of CO_2 in the upper atmosphere that is driving the heating of the earth's atmosphere, measured in parts per million (ppm).

An unusual characteristic of CO_2, unlike methane for example, is that once the gas is released into the upper atmosphere it does not break down. It has an effective atmospheric residence time of centuries to millennia (IPCC 2018 Chapter 1 at 1-23). It is only removed from the atmosphere when it is absorbed by the earth's surface – by dissolving into the upper ocean (and slowly into the deep ocean) or by biological uptake into forests and plants. The problem is that we keep releasing more CO_2 into the atmosphere every year, at a rate that far exceeds the process of natural removal. Once we cease massive fossil fuel burning, the large incremental increases in the atmospheric carbon concentration will stop. After emissions cease, atmospheric CO_2 will begin to decline, albeit very slowly – only over decades and centuries. From the perspective of the time frame that concerns us and our children, beginning now to reduce the rate of increase in the carbon concentration level is essential, and that can only be achieved by absolute *reductions* in the production and combustion of fossil fuels on a global scale.

The defining point is that the additional volumes of CO_2 we release into the atmosphere every year are *cumulative*. It is no solution to say, 'Canada will defer cutting our oil production until sometime after 2030'. Choosing to delay action is hugely consequential. It means we are continuing to contribute to the rapidly accumulating amount of CO_2 in the atmosphere that is driving the heating of the earth's surface.

The most recent measurements of the atmospheric carbon concentration level warn us of the unforgiving timeline we face. Eleven years ago, in the year 2013, the carbon concentration level was 395.3 ppm CO_2. The annual level had increased to 417.2 ppm CO_2 by 2022. That number increased to 420 ppm in 2023. To stay within the 1.5°C warming threshold the atmospheric carbon concentration level must be kept below 430 ppm.

The rate of annual increase has been accelerating, reflecting the persistent annual growth in the volume of global emissions from burning coal, oil, and natural gas. In the 1960s, the rate of growth of the atmospheric carbon concentration level was about 0.6 ppm per year. During the past eight years, it has been rising at an average rate of about 2.4 ppm every year. The increase in 2023 was 2.8 ppm. Given the recent rate of increase, the atmospheric carbon concentration level will exceed 430 ppm CO_2 by 2028.

The above kind of information explains why "near-term" reductions in our oil production are essential and why if we fail to meet the near-term goal we cannot meet the longer-term goal, which is achieving net-zero by 2050 and keeping the temperature increase to less than 1.5°C.

11. The "downstream" emissions released by Canada's exported oil

We are told by Canada's Minister of Environment and Climate Change and by energy economists that, under the Paris Agreement (and under the terms of the UN Framework Agreement on Climate Change that defines what emissions countries are obliged to count in their national emissions accounting) Canada has no obligation to "count" the "downstream" emissions that are released by our exported oil as part of our formal national emissions.

But the accounting rules are not an answer to the problem we face. Global emissions from burning oil, gas, and coal are driving the warming of the earth's surface. That includes the massive volume of the downstream emissions released by our exported oil, which we are planning to increase (or maintain at very high levels) for another 10 or 20 years. There is no existing technology that can "remove" them from the atmosphere once they are released. The fact that the Government of Canada does not "count" them does not halt the warming. The downstream emissions from our exported oil contribute directly to climate change in Canada – to the same extent as if those emissions were released in Saskatchewan or in Nova Scotia.

In terms of magnitude, downstream emissions from our exported oil are *equivalent to the combined total of all the GHG emissions released every year within Canada's borders* from all our industrial activities, transportation (cars, trucks, rail, domestic air, and marine), all buildings, agriculture, electricity generation, and all oil and gas extraction and processing operations within Canada, etc. They will continue to increase in line with our expanding oil exports.

Canada's national emissions in 2022 were 708 million tonnes (Mt) CO_2 eq. When Canada signed the Paris Agreement in 2015, our total domestic emissions were 745 Mt. We have reduced the annual level of our domestic emissions by only 37 Mt over that seven-year period. In that time the downstream emissions from Canada's fossil fuel exports (mainly crude oil and natural gas) have increased from 722 Mt in 2015 to 990 Mt in 2022. Most of that increase was due to the rapid growth of our oil exports. Downstream emissions from Canada's exported oil increased from an annual level of 496 Mt in 2015 to 723 Mt in 2022 – an absolute increase of 227 Mt which has eclipsed many times the modest 37 Mt reduction in Canada's domestic emissions over the same period. In 2023 the annual level of downstream emissions from our oil exports increased again, by another 41.9 Mt CO_2. Measured against those increases, our domestic reductions are insignificant. The amount of CO_2 currently released every year into the atmosphere from the combustion of our exported oil is equivalent to another Canada: an emitting twin we do not talk about, for which we take no responsibility.

The Supreme Court of Canada in its decision on March 25, 2021, in the *Greenhouse Gas Pollution Pricing Act* case, relying on the scientific evidence presented to the Court, clearly and precisely acknowledges the *borderless* way emissions released in one jurisdiction will affect (and drive climate change) in all other jurisdictions. In the Carbon Pricing case, the Court was

required to examine the scientific evidence which explains why GHG emissions released within one province in Canada will impact all the other provinces:

> *"It is also an uncontested fact that the effects of climate change do not have a direct connection to the source of GHG emissions; every province's emissions contribute to climate change, the consequences of which will be borne extra-provincially across Canada and around the world"*
>
> — References re *Greenhouse Gas Pollution Pricing Act*, para 187 (emphasis added)

In the same way, whether they are released by cars and trucks in New York or Shanghai, emissions from our exported oil are contributing directly to climate breakdown in B.C. and Northern Quebec, and they are driving the escalating heat in India and all South Asia, and the horrific drought in the Horn of Africa and across the Sahel, the retreat of glaciers in the Himalayas and Central Asia, acidification of the world's oceans. This catastrophic outcome, which crosses all national borders, is being driven by the physics of climate change. Nothing in the national emissions accounting rules will slow that down or protect us or the world from the consequences of the downstream emissions from our oil exports.

Over 85% of the total life-cycle emissions released by the oil we produce occurs after the extraction process is completed. See *The oilsands in a carbon-constrained Canada*, Pembina Institute, Benjamin Israel et al., February 2020: https://www.pembina.org/reports/the-oilsands-in-a-carbon-constrained-canada-march-2020.pdf. The Pembina report shows that "well-to-wheels" emissions for all types of oil range from a low of about 450 kg CO_2 per barrel up to a high end of about 650 kg CO_2 per barrel. The emissions intensity of Canadian oil sands is at the higher end of that range, about *550 kg CO_2 per barrel* and above that. Oil sands emissions from extraction and production operations within Canada average about 80 kg CO_2 per barrel. They account for less than 15% of the total life-cycle emissions released by each barrel of oil Canada produces. The other 85% of the emissions from every barrel we produce occurs after we export our oil, when it is combusted as fuel in vehicle engines in the U.S and in other foreign markets and released into the atmosphere as tailpipe emissions. Canada's national emissions accounting (the data reported annually by the government to Canadians) does not include that 85%.

Summary

Any discussion that seeks to examine the drivers of human-caused emissions and the science of climate change, and that aims to include discussion about the "solutions" to the situation we face, must address the need for deep reductions in oil, natural gas, and coal production. In the absence of that essential element, all the other emphasis on nature-based solutions e.g., afforestation and regeneration of coastal wetlands, and social and lifestyle changes (e.g., ending "fast fashion"), and the remarkable advances in solar and wind energy technologies will do nothing to lead us out of an inevitable worsening of our present predicament. Fossil fuel combustion emissions every year account for 70% of all human-caused greenhouse gas emissions and about 90% of annual global carbon dioxide emissions. The other issues are an important part of the solution. Unfortunately, oil production is the keystone. Canada is the world's 4th largest oil producer. There is no solution without directly addressing oil production.

I am suggesting that the CER's report of June 20, 2023, and the IEA's pathbreaking May 2021 report offer us a useful and accurate framework to explore this subject which is being excluded from public and political discussion in Canada. Other parts of the available evidence explain the urgency of dealing with oil production, which I briefly summarize here:

- The evidence is clear that based on current levels of oil, gas, and coal production the remaining carbon budget to 1.5°C (which is now 275 $GtCO_2$) will be fully exhausted within about six more years, by 2030 or slightly before that: see Part 3 above. Also, the available data about the atmospheric carbon concentration level confirms that by about 2028-2030 the atmospheric carbon will exceed 430 ppm, the level aligned with 1.5°C: see Part 9.

- After about 2030, all further global emissions from fossil fuel combustion will therefore be driving the world into "overshoot" – that is, driving the earth's average surface temperature above 1.5°C. The "Canada Net-Zero Scenario" is one example of that kind of pathway where, in that case, even moderately delayed cuts in fossil fuel take us to 1.7°C or 1.8°C by 2050 and during the decades after. The higher levels of ongoing oil and gas production described in detail in the IEA's STEPS Scenario will give us warming of 2.4°C by 2100.

- Available evidence shows the annual level of global fossil-fuel combustion emissions we can expect to see every year through to 2050 if we continue high levels of fossil fuel use: see Figure B and Part 4. We can readily calculate, for example, the total cumulative additional amount of CO_2 that under existing plans and policies will be released into the atmosphere over the next 26 years to 2050 (900 $GtCO_2$): Part 4.2. We can compare that to the remaining carbon budget (275 $GtCO_2$).

- We also know that a total of about 220 $GtCO_2$ of "carbon dioxide removals" would be required in future to "roll back" even a small temperature overshoot of 0.1°C: see Part 6.1. Rectifying just 0.1°C degree of overshoot would require about 5 billion tonnes ($GtCO_2$) of carbon removal every year over the 50 years between 2050 and 2100.

- Recent studies reported by the IEA and by other leading research bodies have warned that by 2050 the *feasible upper limit* of achievable carbon removals from the atmosphere by large-scale deployment of CDR technologies (principally BECCS and DACCS) is in the range of 1.7 to 3.0 $GtCO_2$ per year: see Part 6.3. Claims that we can delay deep reductions in oil, gas, and coal combustion and rely on future large-scale carbon removal after 2050 to "roll-back" any substantial overshoot have no foundation in the available evidence.

This paper is a shorter version of a more detailed Working Paper published in November 2024 by UBC Allard School of Law Centre for Law and the Environment: *Canada's Oil Future: Reliance on Carbon Capture and Carbon Removal Technology is a Dangerous Trap*. The Working Paper includes notes and links to recent reports and sources and is found at at https://allard.ubc.ca/sites/default/files/2024-11/2024%2001%20Gooderham%20Canadas%20Oil%20Future.pdf.