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# Extracted Carbon

## Re-examining Canada's Contribution to Climate Change through Fossil Fuel Exports

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# Summary

CANADA HELPED USHER in the Paris Agreement on climate change, but wants to continue reaping the economic benefits of being a fossil fuel exporter.

A major shortcoming of the Paris Agreement is that countries have committed to reducing emissions within their boundaries, but not the carbon that is extracted at home and burned elsewhere. So if Canada expands fossil fuel exports, only the emissions from extraction and processing prior to export are counted in our greenhouse gas (GHG) inventory, not the much-larger emissions when the fuel is combusted in the US or Asia.

This study re-examines Canada's contribution to global climate change in light of the Paris Agreement by looking at *extracted carbon* — the total amount of fossil fuels removed from Canadian soil that ends up in the atmosphere — whether used for domestic purposes, or exported and combusted elsewhere.

We find that:

- In 2015, Canada's extracted carbon equaled almost 1.2 billion tonnes of $CO_2$ that ultimately ended up in the atmosphere.
- Canada's extracted carbon emissions have increased 26 per cent since 2000. This increase is almost exclusively because of Canada's growing exports of fossil fuels, and in particular crude oil.
- Just over-half of the carbon extracted in Canada is used for domestic purposes, and the remainder is exported.
- In 2014, the total amount of emissions from Canada's exports of fossil fuels (738 Mt) was about the same as all GHG emissions that occur in Canada (732 Mt).

## Living within a carbon budget

Signatories to the Paris Agreement committed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Article 2).

This limit on future global emissions is called a *carbon budget*. This report investigates Canada's plausible share of a global carbon budget, and finds that in all cases it is much smaller than Canada's proven reserves of fossil fuels.

Based on Canada's share of global fossil fuel reserves, the resulting carbon budget implies that Canada could extract carbon at current levels for at most between 11 and 24 years (the smaller the carbon budget, the less the damages from climate change). This means a planned, gradual wind-down of these industries needs to begin immediately, rather than the continued pursuit of new fossil fuel infrastructure. Pipelines and new facilities for liquefied natural gas (LNG) will lock Canada in to a high-emissions trajectory for several decades to come.

## Addressing climate change

Neither industry nor government appear to be considering the Paris Agreement in their future planning exercises. In spite of the Agreement, the National Energy Board continues to forecast increases in Canadian fossil fuel production and exports.

Ultimately, government efforts to address climate change must take into account supply-side measures to complement demand-side policies to reduce emissions. These include:

- Stop approving new fossil fuel infrastructure;
- Place a moratorium on issuing new leases for fossil fuel exploration and drilling;
- Increase royalties; and
- Eliminate fossil fuel subsidies.

Canada's exports of fossil fuels do not need to drop to zero immediately, but we cannot pursue policies that further increase extracted carbon. Currently, countries like Canada only have an incentive to get fossil fuels to market as quickly as possible before more stringent policies come into effect.

If all countries were to act like Canada and seek to continue expanding extraction and export of fossil fuels, we are collectively giving up on a limiting warming to 1.5 to 2°C. This is not the future envisioned in the Paris Agreement.

# 1. Introduction: the problem with Paris

> "The atmosphere doesn't care where carbon is emitted. It requires us to take action all around the world."—Prime Minister Justin Trudeau[1]

> "I've said many times that there isn't a country in the world that would find billions of barrels of oil and leave it in the ground while there is a market for it."—Prime Minister Justin Trudeau[2]

WITH THE CLAIM "Canada is back," the new Trudeau government helped usher in the Paris Agreement on climate change in December 2015. The agreement officially came into effect in November 2016, after being ratified by 55 countries representing at least 55 per cent of global emissions.[3] Signatories to the agreement commit to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Article 2) and "to reach global peaking of greenhouse gas emissions as soon as possible" (Article 4).[4]

Back in Canada, however, plans for climate action at the federal and provincial levels have been accompanied by the approval of new fossil fuel infrastructure. The December 2016 federal-provincial-territorial Pan-Canadian Framework on Clean Growth and Climate Change sets a national floor price on carbon (starting in 2018) and aims to phase out coal-fired electricity by 2030. But 2016 also saw federal approvals of the proposed Pacific NorthWest liquefied natural gas (LNG) plant in northern BC, and the smaller Woodfibre LNG facility near Squamish, BC. The federal government also approved two major bitumen pipeline projects: Enbridge's Line 3 replacement and Kinder Morgan's controversial Trans Mountain pipeline expansion.

This paper analyzes Canada's growing export of fossil fuels and its contradictions with the Paris Agreement. A major shortcoming of the Paris Agreement is that countries have committed to reducing emissions within their borders, but *not the carbon that is extracted at home and burned elsewhere*. For example, when Canada expands its production of fossil fuels, only the emissions from extraction and processing prior to export are counted in Canada's greenhouse gas (GHG) inventory, not the much larger emissions when those exported fossil fuels are combusted in the United States or Asia.

Exported emissions would not necessarily be a concern if the pledges submitted by signatory countries to the Paris Agreement were consistent with the Agreement's 1.5 to 2°C temperature target. Unfortunately, this is not the case. A 2016 report from the United Nations Energy Program concluded that even if all countries fully implement their pledges (called Intended Nationally Determined Contributions, or INDCs) it would still lead to global warming in 2100 of 3.0°C.[5] Global emissions in 2030 need to fall a further 22% (12 billion tonnes (gigatonnes) of carbon dioxide, or 12 Gt $CO_2$) for the world to be on a 2°C pathway, and 28% (15 Gt $CO_2$) for a 1.5°C pathway.

Although the Paris Agreement requires countries to periodically upgrade their GHG reduction targets, it may be several years before countries have to revisit their targets, and ultimately there are no penalties for failing to meet them. Moreover, Canada's climate action efforts fall short of Canada's 2030 pledge to the Paris Agreement of a 30 per cent reduction by 2030 (relative to 2005 levels). The December 2016 Pan-Canadian Framework will miss the mark by 44 million tonnes (Mt).[6]

This report makes the point that the targets themselves fail to include a very large share of the carbon that Canada extracts each year and that ends up in the atmosphere. Canadians want their governments to lead on climate change, and they are willing to make changes to their lives and to the economy to reduce emissions. But if these reductions are accompanied by rising fossil fuel exports, Canada's real impact on climate action will be very little.

The next section revisits Canada's emission trends, with an eye to the total amount of carbon being extracted as fossil fuels from Canadian soil and traded internationally. Section 3 then reviews the recent literature on carbon budgets — the total amount of carbon that can be emitted going forward before we pass key temperature thresholds — and considers Canada's plausible share of a science-based carbon budget. Section 4 looks at the potential emissions arising from new fossil fuel development and infrastructure being proposed for the country, and how these compare with a carbon budget. The final section reviews supply-side policies to keep carbon in the ground as a complement to demand-side policies.

# 2. Carbon emissions and Canadian trade

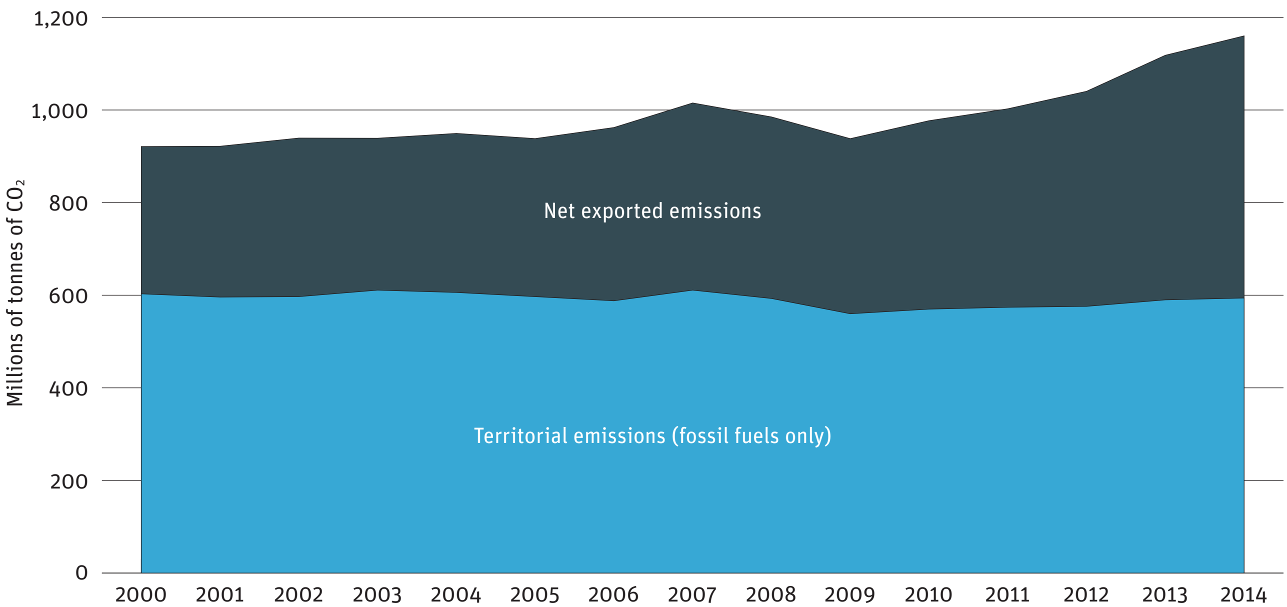
THIS SECTION RE-EXAMINES Canada's contribution to climate change by looking at *extracted carbon:* the total amount of fossil fuels removed from below ground that end up in the atmosphere. This measure considers both domestic uses (territorial emissions) as well as international trade in fossil fuels (net exports). See sidebar (page 14) for definitions of different emission measures. This report uses Statistics Canada data on exports and imports of fossil fuels (oil, gas, coal and petroleum products), converted into $CO_2$ emissions using standard emission factors in Canada's National Inventory Report.[9]

*Figure 1* shows Canada's extracted carbon emissions going back to 2000, broken down into territorial emissions and net exports. At 1,160 million tonnes carbon dioxide (Mt $CO_2$), extracted carbon emissions in 2014 were up 26 per cent from 2000 levels. Just over half of the carbon extracted in 2014 is used for domestic energy consumption, while the other half represents net exports of carbon.

The growth in extracted carbon since 2000 is thus almost entirely an export story, as net exports of emissions (i.e., emissions embodied in Canada's fossil fuel exports less imports) grew 78 per cent between 2000 and 2014 (in dark blue). In contrast, Canada's territorial emissions from the use of fossil fuels for energy (in light blue) going back to 2000 were relatively flat (a drop of 1.5 per cent by 2014). Some key changes over this timeframe

**FIGURE 1** Canada's extracted carbon: territorial emissions and net exports (converted to Mt $CO_2$), 2000 to 2014

In light blue are territorial emissions from the use of fossil fuels for energy, as reported in Canada's National Inventory Report. In dark blue are net exports, the emissions embodied in fossil fuels exported from Canada, less emissions embodied in imports. The sum of these two lines represents extracted carbon, the total amount of fossil fuels from Canadian soil that ultimately ends up in the atmosphere as $CO_2$.




**Note** Territorial emissions are for energy from fossil fuels only, and do not include non-fossil-fuel GHG emissions from agriculture, waste or industrial processes.
**Sources** Territorial emissions from National Inventory Report. Exported and imported emissions calculated by author from CANSIM matrices 131-0001, 126-0001, 134-0004 and Merchandise Trade database catalogue #2701 and 2702, Statistics Canada. Emission Factors from Annex 6 of Canada's National Inventory Report and British Columbia's Provincial Inventory Report.

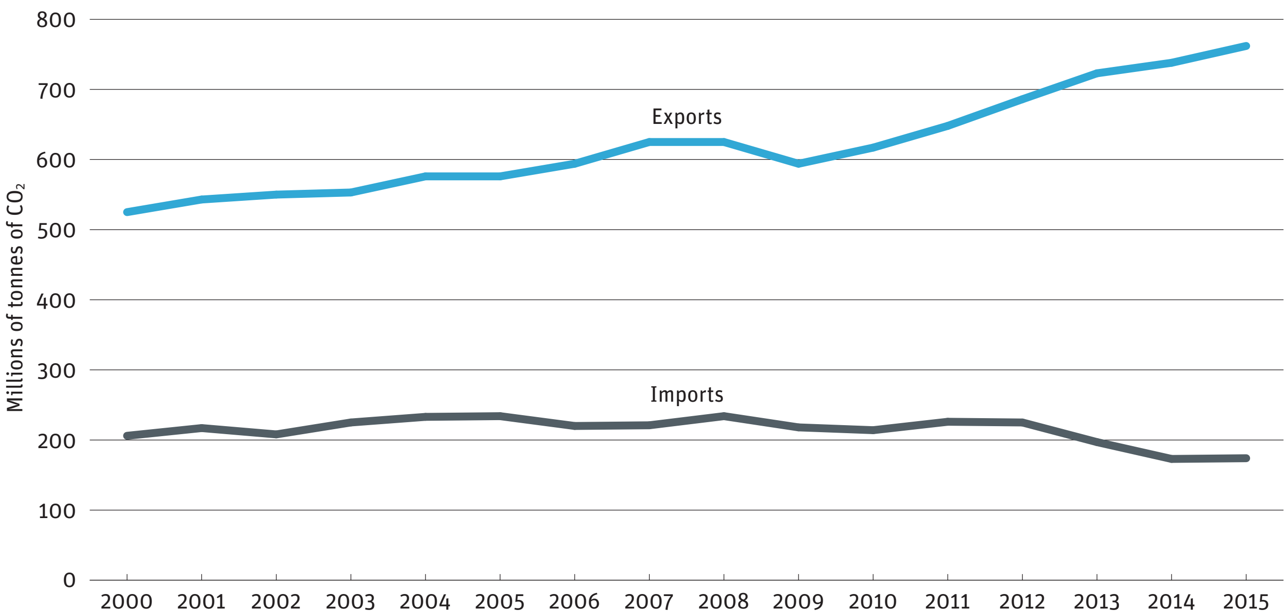
include emission reductions from the phase out of coal-fired power in Ontario (down 37 million tonnes [Mt]) and the Maritimes (down 7 Mt); these have been offset by the growth in emissions from extracting and processing fossil fuels (up 33 Mt) and from transportation (up 15 Mt).[10]

In 2014, the industrial emissions attributable to production of fossil fuels (i.e. the oil and gas sector's mining/drilling, upgrading, processing and refining activities in Canada) were 192 Mt $CO_2$. This is 17 per cent of the 1,160 Mt $CO_2$ in total extracted carbon. That is, about one out of every six units of fossil fuel extracted in Canada is used to power the oil and gas industry's activities.

*Figure 2* breaks down net exports of emissions from trade in fossil fuels. Emissions embodied in Canada's fossil fuel exports grew a total of 45 per cent between 2000 and 2015 (although the National Inventory data only go

**FIGURE 2** Canada's trade in fossil fuels, 2000 to 2015 (converted into Mt $CO_2$)

This figure breaks down "net exports" from Figure 1 into the emissions embodied in Canada's exports and imports of fossil fuels. Emissions embodied in Canada's exports increased between 2000 and 2015, while emissions embodied in imports fell. Canada's net exported emissions thus grew at a faster rate than just exports alone.



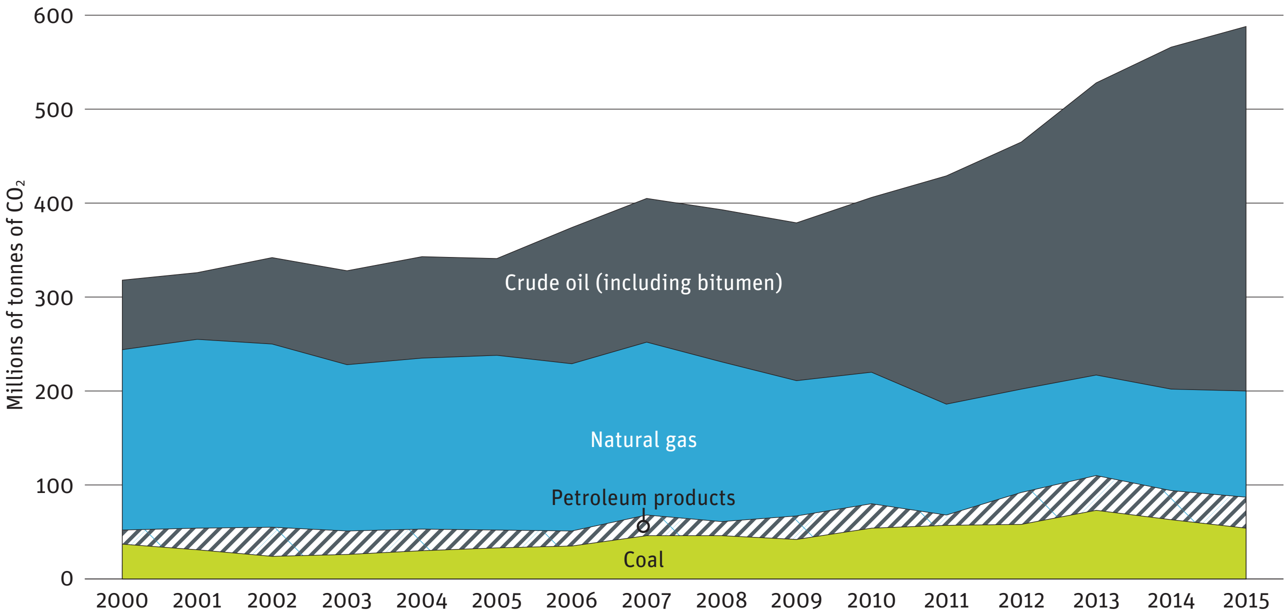

**Sources** Author's calculations based on CANSIM matrices 131-0001, 126-0001, 134-0004 and Merchandise Trade database catalogue #2701 and 2702, Statistics Canada; and emission factors from Annex 6 of Canada's National Inventory Report and British Columbia Provincial Inventory Report.

to 2014, from export data we can calculate to 2015). Crude oil (including bitumen) led the overall increase, with a 119 per cent rise over the full 2000 to 2015 period. Exported emissions from petroleum products also grew 71 per cent over this period.

In contrast, emissions embodied in Canada's imports of fossil fuels fell by 15 per cent between 2000 and 2015. This includes a 38 per cent drop in crude oil imports and a 63 per cent drop in coal imports. These decreases were partially offset by increased natural gas imports, which were negligible in 2000 but grew steadily over this timeframe, and increases in petroleum product imports.

One other interesting observation is that the 2014 emissions from total exports in *Figure 2* (738 Mt) were slightly larger than *all greenhouse gas emissions* in Canada's National Inventory Report (that is, if we also add in *non–fossil fuel emissions* in agriculture, waste and industrial processes to the territorial emissions from using fossil fuels), which were 732 Mt in 2014.

**FIGURE 3** Canada's net exports of fossil fuels by type (converted into Mt $CO_2$), 2000 to 2015




**Sources** CANSIM matrices 131-0001, 126-0001, 134-0004 and Merchandise Trade database cat. #2701 and 2702, Statistics Canada. Emission Factors from Annex 6 of Canada's National Inventory Report and the BC Provincial Inventory Report.

*Figure 3* breaks down emissions embodied in Canada's *net exports by type of fossil fuel* from 2000 to 2015. The major story is the growth in net exports of crude oil, the single-largest export category. With exports up and imports down, net exports were 388 Mt $CO_2$ in 2015, some 423 per cent higher than in 2000. In 2015, crude oil exports increased 9 per cent despite a substantial drop in oil prices. This result suggests that major oil producers increased production to get positive cash flow, having already sunk billions of dollars into getting oil sands operations up and running.

Natural gas net exports went in the opposite direction, largely reflecting a major decline in exports from Alberta, but also growing imports. Net exports fell by 41 per cent to 113 Mt $CO_2$ in 2015 compared to 2000. This decline also represents growing domestic demand for gas as an input into oil sands processing. Gas production in British Columbia has been growing in recent years, and has the potential to surge if proposed LNG developments occur (more on this in Section 4).

The last two categories are much smaller in terms of trade. Petroleum products more than doubled net exports to 33 Mt in 2015 relative to 2000.

### Accounting for carbon emissions

There are three ways to measure a country's contribution to global climate change and to account for the carbon emissions embodied in international trade flows.[7] These three concepts together consider that fossil fuels may be extracted in one country, burned to manufacture goods in a second country and consumed by the citizens of a third country.

**Territorial emissions** are greenhouse gas emissions that occur *within* national borders. This is the conventional measure used in Canada's National Inventory Report, the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. This measure includes emissions from the use of *fossil fuels for energy* (fossil fuel combustion and fugitive emissions such as methane leakages) as well as emissions from *non–fossil fuel sources* (e.g., emissions from landfills and agricultural practices, industrial processes such as making cement).

This conventional UN framework of territorial emissions does not reflect the reality of globalization and international trade. National economies are interlinked through extensive trade relationships and supply chains, including trade in both fossil fuels themselves and goods and services that use fossil fuels in their manufacture.

**Consumption emissions**, or **carbon footprint**, are emissions associated with the *final goods and services consumed by a country*, wherever those emissions may be released into the atmosphere. This measure overlaps with territorial emissions for fossil fuels that are both extracted and combusted in Canada. The key difference is that Canada's carbon footprint would, for example, include emissions from coal-fired power used in China to manufacture consumer electronics purchased in Canada; and subtract emissions in Canada used to manufacture goods exported to, and consumed in, the United States. Technically, carbon footprint is equal to *territorial emissions* plus the carbon embodied in the *net exports of final goods and services.*

Coal net exports were up 46 per cent to 54 Mt $CO_2$ in 2015 compared to 2000; they grew until 2013 but have since declined.

Putting these pieces together, it is clear that Canada's flat profile for territorial emissions tells only part of the story about Canada's contribution to global climate change. Canada has been greatly increasing its exports of fossil fuels, particularly crude oil, and therefore also adding to the total amount of carbon that eventually ends up in the atmosphere. However, only half of the emissions from Canada's extracted carbon are counted in our national inventory. Thus, the conventional way of carbon accounting (territorial emissions), which is central to the Paris Agreement, is more favourable to Canada than when we account for net exports and look at extracted carbon.

Continuing to expand exports of fossil fuels, and net exported emissions, is clearly contradictory to the spirit and intentions of the Paris Agreement.

A country's carbon footprint is estimated using complex multi-regional input-output models, an exercise this paper does not undertake. A 2015 study from the Organization for Economic Co-operation and Development (OECD) found that Canada's carbon footprint grew by 18 per cent between 2000 and 2011 compared to only 2 per cent growth in territorial emissions. It also found that Canada's carbon footprint in 2011 was about 8 per cent larger than its territorial emissions.[8]

**Extracted carbon** is the *total amount of fossil fuels removed from below ground* each year (converted into carbon dioxide emissions [$CO_2$]). This measure is the same as the reduction in a country's fossil fuel reserves. Technically, extracted carbon is equal to *territorial emissions* plus *net exports of carbon embodied in traded fossil fuels.* That is, fossil fuels removed from the ground in Canada are either combusted in Canada or in an export market. Just as we count the emissions embodied in the fossil fuels we export, we must also deduct the emissions embodied in the fossil fuels we import.

Extracted carbon is the focus of this paper. This measure is much broader than calculating the emissions in Canada from fossil fuel extraction industries (for example, mining and upgrading oil sands, or fracking and processing shale gas). Put another way, some portion of extracted carbon is used to power the facilities, machinery and equipment of fossil fuel industries, and the remainder can be used for other domestic purposes or be exported.

Extracted carbon and the carbon footprint should be viewed as *complementary approaches* to the conventional UN framework based on territorial emissions alone. They need not replace territorial emissions, but they do provide alternative perspectives that can guide policy-makers toward reducing the global emissions that are of concern to all countries. In Canada, as a major exporter of fossil fuels, the extracted carbon concept is highly relevant.

Increasing exports also adds to the global supply glut and low fossil fuel prices, worsening the economic case for getting off of fossil fuels (relative to the costs of renewables). The next section looks at what limits could be expected if countries were to take the Paris Agreement seriously.

# 3. Living within a carbon budget

A *CARBON BUDGET* is a ceiling on total greenhouse gas emissions that is consistent with keeping global temperature increase below a specified threshold. Often this is 2°C above pre-industrial levels (about 200 years ago), but carbon budgets can also be specified for lower thresholds, such as the 1.5°C aspirational target in the Paris Agreement, or higher, such 3°C. The last major report of the Intergovernmental Panel on Climate Change (IPCC) set out a series of "carbon budgets" for these temperature targets of 1.5, 2 and 3°C, and at different levels of probability of staying below for each.[11]

A number of observers have commented that available fossil fuel reserves are substantially larger than a 2°C carbon budget, meaning a majority of fossil fuel reserves represent "unburnable carbon."[12] Most recently, a 2016 report by Oil Change International evaluates data on global fossil fuel reserves, using two Paris-based carbon budgets for cumulative emissions up to 2100: a budget of 843 billion tonnes of carbon dioxide (Gt $CO_2$), which represents a likely (66%) chance at staying below 2°C above pre-industrial levels; and a budget of 393 Gt $CO_2$, which is a medium (50%) chance at staying below 1.5°C. To put this carbon budget in context, in 2014 global emissions were 35.7 Gt $CO_2$.

A central conclusion of the OCI report is that the emissions associated with exploiting all remaining reserves from existing projects (e.g. oil and gas fields, and coal mines already operating) would push the planet past

## A note on reserves

Although the concept of fossil fuel reserves may appear to be straightforward, in practice definitions differ according to the likelihood that these reserves can be recovered. The most firm reserve statistic is *proven (or proved) reserves,* also known as *remaining established reserves*, which are known reserves that are recoverable with available technology and in current economic conditions. These amounts will almost certainly be extracted, and as technology improves, the amount of proven reserves will increase. A subset, *developed reserves*, refers to reserves from existing oil and gas fields and coal mines that are already operating and have extraction infrastructure in place.

Two broader estimates of reserves reflect the range of uncertainty around total recoverable volume. Proven plus probable (2P) reserves estimate the likely actual amount that will eventually be extracted. Proven plus probable plus possible reserves (3P) represent a high estimate, much of which is not likely to be recoverable.

In addition to reserves are broader categories of *resources*. Beyond 3P reserves, the total resource includes discoveries that are not commercially or technologically viable under current conditions, plus potential future discoveries.[13]

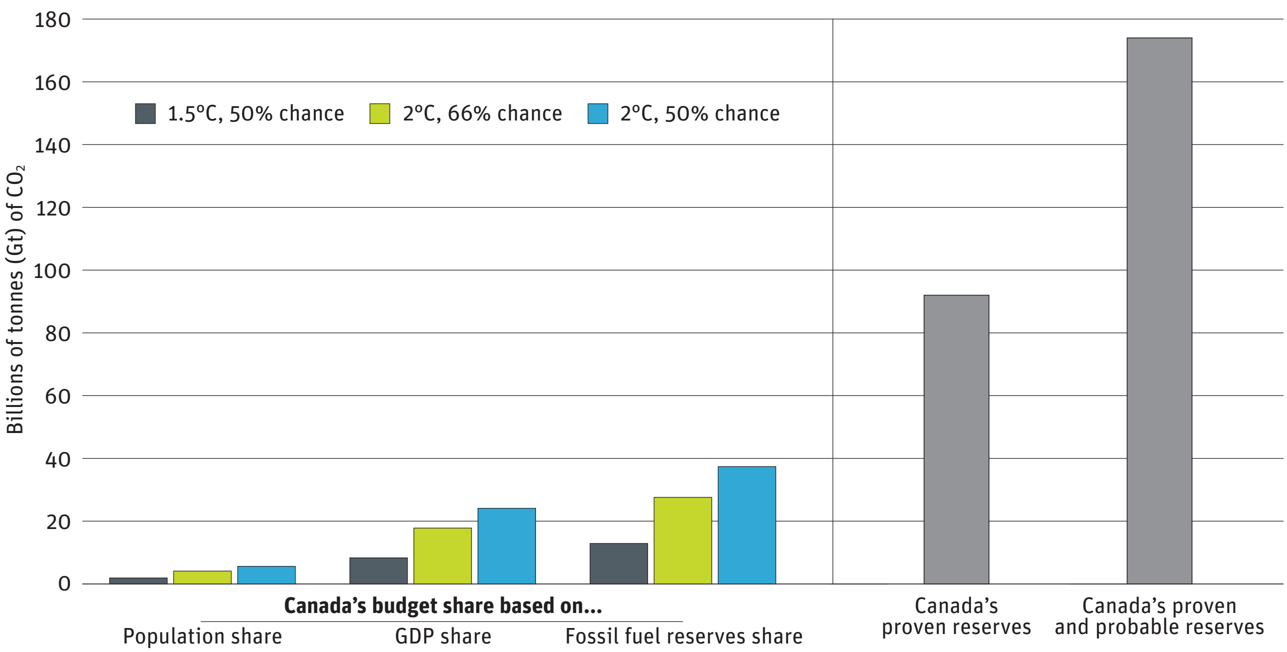
2°C. For a likely chance at keeping warming below 2°C, some 68% of global reserves need to stay underground; for a medium chance of staying below 1.5°C, 85% of these reserves must stay underground.

How a global carbon budget would be distributed across individual countries is uncertain; it would inevitably be the outcome of political forces and negotiations, but it would also have to be shaped by principles of equity and fairness. Allocating a global carbon budget based on population would be the most equitable approach and would best correspond with the alternative indicator, carbon footprint (see sidebar, section 2). A carbon budget based on GDP or share of current emissions might accord with territorial emissions. These options have been considered in previous research and are shown in *Figure 4* for comparative purposes.[14] Whichever method of allocation is used, Canada's proven reserves are vastly greater than a plausible carbon budget for the country.

Because *extracted carbon is the same as a reduction in reserves*, we consider allocating a global carbon budget based on shares of fossil fuel production and proven reserves to provide a plausible range of carbon budgets for Canada. In 2015, Canada was the source of 4.8 per cent of world oil supply, 4.6 per cent of natural gas and 0.8 per cent of coal. Altogether, Canada was responsible for 3.0 per cent of global fossil fuel supply. For proven reserves,

**FIGURE 4** Canada's share of a global carbon budget using different concepts and probabilities vs. reserves of fossil fuels (converted into Gt $CO_2$)

This figure shows Canada's plausible share of a global carbon budget, based on share of world population, share of world GDP and share of fossil fuel reserves (latter is used in Table 1). For each we show three different probabilities of the world meeting temperature targets consistent with the Paris Agreement: a 50% chance of staying below 1.5°C above pre-industrial levels, a 66% of staying below 2°C, and a 50% chance of staying below 2°C. All of these estimates yield carbon budgets for Canada that are substantially smaller than estimates of Canada's fossil fuel reserves.




**Sources** Author's calculations based on carbon budget estimates from the Intergovernmental Panel on Climate Change (2014) and Oil Change International (2016); population data from United Nations and Statistics Canada; GDP data from the World Bank; proven reserves from the BP Statistical Review of World Energy 2016.

Canada's share of the global pie is slightly larger, with about 3.3 per cent of world fossil fuel reserves, and by category: 10.1 per cent of oil reserves, 1.1 per cent of gas reserves and 0.7 per cent of coal reserves.[15]

For the rest of this paper, only carbon budgets based on share of proven reserves are used. A carbon budget share of 3.3 per cent may be overly generous to Canada due to the high-cost nature of its reserves (more on this below). But that figure is a plausible upper limit on the share of global reserves Canada could credibly claim to extract in a carbon-constrained world.

*Table 1* uses Canada's share of global proven reserves to develop a plausible range for a Canada of a global carbon budget. Two options are based on the two Oil Change International scenarios, and a third is based on a more

**TABLE 1** Implications of a Carbon Budget for Canada, three scenarios

| | Carbon budget scenario | | |
|---|---|---|---|
| | 50% chance of staying below 1.5°C | 66% chance of staying below 2°C | 50% chance of staying below 2°C |
| Global carbon budget (Gt $CO_2$) | 393 | 843 | 1143 |
| Canadian carbon budget based on share of proven reserves (Gt $CO_2$) | 12.9 | 27.6 | 37.4 |
| Number of years at 2014 extracted emissions | 11.1 | 23.8 | 32.2 |
| Share of proven reserves that need to stay underground (%) | 86 | 70 | 59 |

**Sources** Author's calculations based on Climate Change 2014: Synthesis Report, Table 2.2, p. 68, http://ipcc.ch/pdf/ assessment-report/ar5/syr/AR5_SYR_ FINAL_All_Topics.pdf; Greg Muttitt, "The Sky's the Limit: Why the Paris Climate Goals Require A Managed Decline of Fossil Fuel Production," Oil Change International, September 22, 2016, http://priceofoil.org/2016/09/22/the-skys-limit-report/.

generous scenario (from the IPCC) of a 50 per cent chance of staying below 2 degrees Celsius. The resulting carbon budgets range between 13 and 37 Gt $CO_2$, though the smaller the carbon budget, the less are the damages from climate change (if all countries similarly did their part).[16] The highest budget represents a coin-toss chance at staying below 2 degrees and is not advisable.

Linking back to our estimate of extracted emissions in the previous section, *these carbon budgets represent between 11 and 32 years of extracted carbon at 2014 levels, with a middle estimate of just under 24 years*. If Canada were to increase its extracted carbon level into the future, it would exhaust its available carbon budget much sooner. Canada's proven reserves, converted into $CO_2$, are estimated at 92 Gt, and a broader category of proven-plus-probable reserves, at 174 Gt.[17] Even at the largest carbon budget of 37 Gt, 60 per cent of Canada's proven reserves and almost 80 per cent of proven-plus-probable reserves would need to stay in the ground.

Christophe McGlade and Paul Ekins of the Institute for Sustainable Resources modeled carbon budget implications in greater detail and attempted to consider *which reserves* would be kept underground: by type of fossil fuel (oil, gas or coal) and by region. Their high-level conclusion was that 82 per cent of the world's proven coal reserves, 49 per cent of the gas reserves and 33 per cent of oil reserves must remain unburned.[18]

They used an integrated assessment model, which uses both climate and economic data, and drew their conclusions based on the assumption that the least-cost reserves would be exploited up to a carbon budget.[19] For Canada, 74 per cent of oil reserves must stay underground, 24 per cent of gas and 75 per cent of coal reserves. In a broader category of proven-plus-probable reserves, 99 per cent of unconventional and 72 per cent of conventional oil resources are unburnable, as are 71 per cent of unconventional and 73 per cent of conventional gas resources, and 98 per cent of coal resources.

Of note, McGlade and Ekins estimate the world will still be using fossil fuels in 2050. Their model relies heavily on gas substituting for coal, and assumes "negative emission" technologies (such as bioenergy with carbon capture and storage) exist after 2050. The assumption that we will be able to rely on technologies that do not currently exist in commercial form, are expensive and may not scale to the magnitude of the problem is among the biggest criticisms of climate-economy models such as this one. Nonetheless, McGlade and Ekins conclude: "[P]olicy makers' instincts to exploit rapidly and completely their territorial fossil fuels are, in aggregate, inconsistent with their commitments to this [2°C] temperature limit."

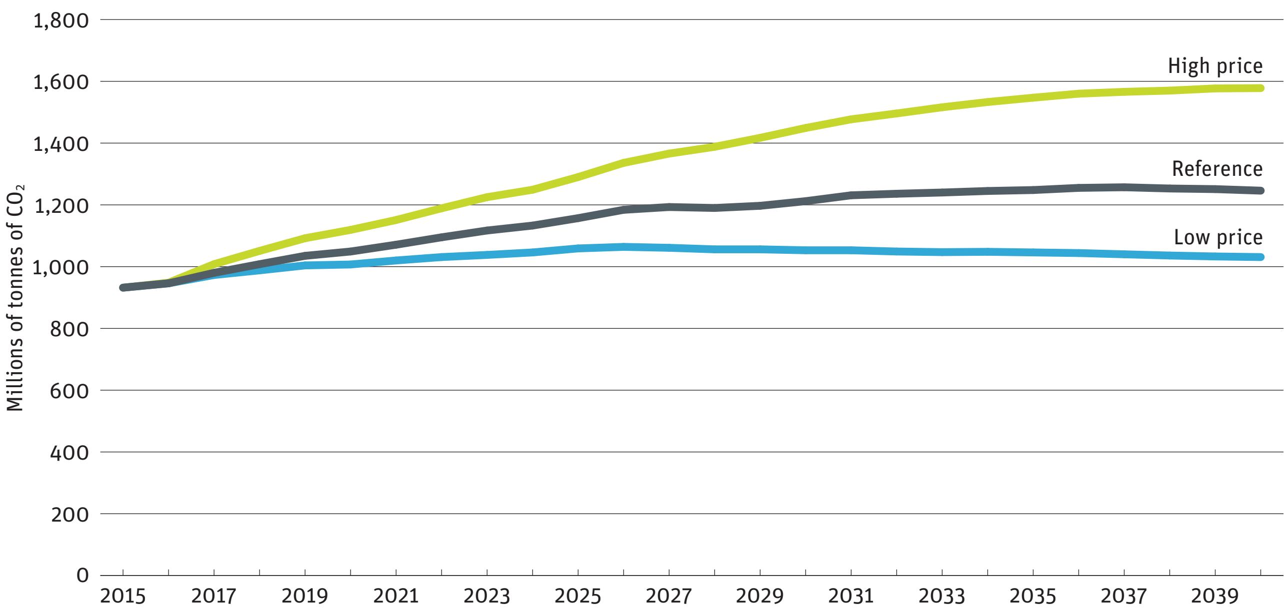
# 4. Planned expansion of fossil fuel production and exports

IN THIS SECTION we look at new infrastructure proposals for the expansion of fossil fuel exports. One important reason to consider investments in fossil fuel infrastructure is *carbon lock-in*, the idea that new production capacity ensures a certain amount of carbon emissions moving forward, which makes it more difficult to achieve emission-reduction targets. This concept applies particularly to very capital-intensive projects in oil and gas, which once built are less sensitive to changes in market price or carbon pricing as long as their operating costs can be covered. Carbon lock-in applies much less to coal projects, which are more labour intensive.[20]

Neither industry nor government appears to be considering the Paris Agreement in its future planning exercises. The National Energy Board (NEB), for example, continues to forecast increases in Canadian fossil fuel production and exports. How much growth we can expect is a function of the path of future commodity prices. Higher prices make investments in fossil fuels such as the oil sands more profitable, which leads to more supply. In contrast, lower prices make investments in fossil fuels less lucrative and can threaten to permanently derail some planned new production.

*Figure 5* shows projections for oil and gas production together, converted into carbon emissions, based on estimates by the NEB.[21] In its reference case

**FIGURE 5** Canada's extracted carbon from oil and gas (Mt $CO_2$), projected, 2015 to 2040




**Sources** Author's calculations based on National Energy Board and standard emission factors (see Section 2).

for oil production, the scenario the NEB considers the most likely to occur, carbon emissions are projected to grow by 41 per cent above 2015 levels by 2040. However, the prices associated with the reference case in the short term are highly optimistic relative to what industry analysts are expecting. Under the NEB's low-price scenario, extracted carbon emissions would be 16 per cent higher in 2040 than in 2015; a high-price scenario would lead to 65 per cent higher emissions. For natural gas, the NEB forecasts growth of 18 per cent in 2040 relative to 2015 for the reference case, with a range between no growth (low price) and 79 per cent (high price). All of these scenarios include one major LNG plant.[22]

Summed together and converted into $CO_2$ emissions, the cumulative extracted carbon between 2016 and 2040 ranges from 19 to 23 billion tonnes (Gt $CO_2$) for oil, and between 7 and 11 Gt $CO_2$ for gas (note that *Figure 5* measures millions not billions). In comparison, a carbon budget consistent with the Paris Agreement (as estimated in the previous section) is between 13 and 28 Gt $CO_2$ (low and middle estimates). Even in the NEB low price scenario, meaning without substantial increases in production, the cumulative extracted carbon (19 Gt for oil and 7 Gt for gas) almost exhausts the carbon budget by 2040.

Moving in the other direction is coal, though the NEB forecasts are not particularly informative. The NEB's January 2016 reference case estimates stable coal exports through 2040, much of which may be metallurgical coal for steelmaking. The October 2016 update estimates a 72 per cent decline in domestic demand for coal due to the push to eliminate coal-fired electricity production by 2030, but it does not provide a new reference case for total production.

## Liquefied Natural Gas (LNG)

The National Energy Board has already approved massive amounts of export capacity for LNG, though only a few projects have completed environmental assessment approvals and are considered serious contenders for a final investment decision. To date, only one small LNG terminal (Woodfibre near Squamish, BC) has received a final investment decision. The leading proponent for LNG on the north coast of BC, the Petronas-led Pacific NorthWest LNG project, received federal environmental approval in October 2016, but has not committed to a final investment decision.[23]

LNG development in BC is an excellent example of carbon lock-in. Once built, an LNG terminal will have a steady profile of emissions for several decades, plus any other emissions associated with the extraction and transport of the gas. While the economics of LNG are highly unfavourable right now,[24] it is still worth contemplating the scale of export expansion that federal and provincial governments have endorsed.

*Table 2* looks at Pacific NorthWest and four other LNG proposals (planned initial capacity only), and assumes that LNG exports represent new incremental gas production. For example, the table estimates only Pacific NorthWest's proposed *initial phase* of 7.6 Mt of LNG exported per year (full capacity would be 18 Mt of LNG). Nonetheless, even this lesser amount is equal to exported emissions of 20 Mt $CO_2$ per year. Adding gas that would be used at various stages of extraction, processing, transportation and liquefaction,[25] these emissions total 29 Mt $CO_2$ per year in additional extracted carbon.

The smaller Woodfibre plant is a second case of interest. It will use low-carbon grid electricity (at subsidized prices) rather than gas to power its liquefaction plant, making it what has been called a "clean LNG" project. Nonetheless, even this small plant would contribute 6.2 Mt $CO_2$ of extracted carbon per year. Over 30 years, LNG plants would have a small but not insignificant impact on Canada's estimated carbon budget, ranging from 0.7

**TABLE 2** Potential extracted carbon from proposed LNG facilities

| | Woodfibre | LNG Canada | Kitimat LNG | Pacific NorthWest LNG | Prince Rupert LNG |
|---|---|---|---|---|---|
| Initial capacity (MT of LNG) | 2.1 | 12 | 5 | 7.6 | 18 |
| Exported emissions per year (Mt $CO_2$) | 5.6 | 32.2 | 13.4 | 20.4 | 48.2 |
| Extracted carbon per year (Mt $CO_2$) | 6.2 | 46.3 | 19.3 | 29.3 | 69.5 |
| Extracted carbon over 30 years (Mt $CO_2$) | 185.7 | 1389.1 | 578.8 | 879.7 | 2083.6 |
| Share of carbon budget (middle estimate) (%) | 0.7 | 5.0 | 2.1 | 3.2 | 7.5 |

**Sources** Author's calculations based on proponent information and emission factors (see Section 2).

per cent for Woodfibre up to 7.5 per cent for Prince Rupert LNG (based on the middle case in the previous section).

These estimates are conservative in that they do not estimate climate impacts from fugitive emissions (leakages) of methane from fracking and processing up to final combustion. Methane is a potent greenhouse gas that traps 86 times more heat than carbon dioxide over a 20-year period, and 34 times over a 100-year period. As a result, even very small amounts of leakage have significant climate impacts. For example, a methane leakage rate of 1 per cent from the Pacific NorthWest development over its whole lifecycle would be equivalent to between 7 and 17 Mt $CO_2$ per year. Real-world estimates put leakages at higher levels.[26] A 3 per cent leakage rate ranges from 21 to 52 Mt $CO_2$ per year. The federal government has pledged to reduce fugitive methane emissions from upstream oil and gas by 40 per cent, though at present little is being done to even accurately measure the extent of the problem.

The BC government frequently claims that LNG exports would contribute to lower global emissions because gas would displace dirtier coal. It is true that at the point of combustion, gas yields fewer emissions than coal per unit of energy produced. However, there is no guarantee that gas will displace coal in Asian export markets. Instead, gas could become an additional source of fuel to meet growing demand in these markets (for example, in China). Or it could displace low-emission nuclear or renewable power (for example, in Japan or Korea). Finally, David Hughes finds that if lifecycle emissions are included (including methane leakages), BC LNG is over 20 per cent more emissions-intensive than coal over a 20-year timeframe.[27] For the most part, arguments about gas being a "bridge fuel" that reduces global GHGs as users switch from coal are but wishful thinking.

**TABLE 3** Potential extracted carbon from proposed bitumen pipelines

| | Enbridge Line 3 | Kinder Morgan TMX | Energy East | Keystone XL |
|---|---|---|---|---|
| Capacity increase (barrels per day) | 370,000 | 590,000 | 1,100,000 | 830,000 |
| Exported emissions per year (Mt $CO_2$) | 37 | 59 | 109 | 82 |
| Extracted carbon per year (Mt $CO_2$) | 53 | 84 | 156 | 118 |
| Extracted carbon over 30 years (Mt $CO_2$) | 1,576 | 2,513 | 4,686 | 3,536 |
| Share of carbon budget (middle estimate) (%) | 5.7 | 9.1 | 17.0 | 12.8 |

**Note** To estimate GHG emissions, total annual LNG flow is reduced by 30 per cent to account for diluent mixed in to enable flow through the pipelines, and assumes the pipeline functions at 90 per cent of capacity. In the case of Enbridge Line 3 and Kinder Morgan TMX, only the increase above and beyond the existing pipeline is counted. Total capacity would be 760,000 and 890,000 barrels per day respectively.
**Sources** Author's calculations based on information provided by proponents.

## Pipelines

Proposals for new pipelines have become a hot-button issue across Canada and into the United States. TransCanada's Keystone XL pipeline, long desired by oil sands producers, was rejected by the Obama administration in part due to climate impacts: "If we're going to prevent large parts of this Earth from becoming not only inhospitable but uninhabitable in our lifetimes, we're going to have to keep some fossil fuels in the ground rather than burn them and release more dangerous pollution into the sky."[28] The project, however, has been revived by the new Trump administration.

In Canada, the Trudeau government rejected Enbridge's Northern Gateway pipeline (previously approved by the Harper government). However, in November 2016 the new government did approve Kinder Morgan's equally controversial Trans Mountain pipeline expansion (TMX) to Vancouver, and Enbridge's Line 3 expansion to Superior, Wisconsin. Some uncertainty still exists about whether these pipelines will go ahead. In addition, TransCanada's Energy East pipeline is pending approval, and would go to Saint John, New Brunswick.

*Table 3* shows the proposed increased export capacity for these four pipelines, and the incremental greenhouse gas emissions per year that would result. The table assumes all of that new pipeline capacity facilitates increased production from the Alberta oil sands, which is consistent with projections from the NEB above.[29] The table shows increased extracted carbon: exported emissions, estimated at 70 per cent of the total, plus emissions in Canada from extraction and processing.[30]

Adding together the emissions over a 30-year estimated lifespan of the pipeline yields an estimate of the total extracted carbon. These latter amounts from pipelines represent a sizeable share of the carbon budget estimated in the previous section. It is remarkable that just the *incremental emissions from bitumen pipelines* would constitute a significant share of a realistic carbon budget for Canada. They would certainly move Canada in the wrong direction with regard to extracted carbon emissions, at a time when the country has promised to reduce its emissions and become part of the solution.

# 5. Next steps for true climate leadership

GERMAN ECONOMIST Hans-Werner Sinn coined the term "the green paradox" to refer to the powerful incentive fossil fuel–producing countries have to respond to future carbon constraints by doubling down on fossil fuels now, "to pre-empt the corresponding wealth losses by extracting and selling their fossil fuels before their markets disappear."[31] In Canada, the only incentive our political leaders have is to reduce extraction and processing emissions within the country. This paradox may help to explain why governments pursue climate action on the one hand and new fossil fuel exports on the other.

As noted in the introduction, national commitments under the Paris Agreement are still far from a 2°C (or lower) pathway, and Canada has some work to do to meet its own inadequate 2030 target. Under Paris, Canada could theoretically reduce its territorial emissions and meet its Paris commitments, while continuing to expand its fossil fuel exports. In contrast, under a meaningful plan that would ratchet up emission reduction targets consistent with a 2-degree pathway, countries such as Canada could only increase fossil fuel exports if other producers agreed to keep more of their reserves in the ground.

Ultimately, a framework of global fossil fuel supply management, within a carbon budget, may be necessary to adhere to the Paris targets. In the absence of such supply-side thinking, the prospect of constrained carbon emissions in the future may drive countries such as Canada to get as much fossil fuel out of the ground and to market now, lest it be "stranded" below ground in the future.

Most climate change mitigation policies focus on the demand side, including efforts to reduce consumption by setting carbon-pricing regimes, improving energy efficiency or shifting to renewables. These demand-side strategies should be complemented by supply-side policies to keep carbon in the ground. In recent years, a number of such policies have been discussed and are relevant to reimagining climate policy to account for extracted carbon:[32]

1. *Stop approving new fossil fuel infrastructure*, including LNG terminals and pipeline capacity. Instead, Canada should aim for a managed transition that steadily removes fossil fuel infrastructure while investing heavily in green infrastructure alternatives.

2. *Place a moratorium on issuing new leases for fossil fuel exploration and drilling rights*. As the recent Oil Change International study found, "Potential carbon emissions from the oil, gas, and coal in the world's currently operating fields and mines would take us beyond 2°C of warming" and "reserves in currently operating oil and gas fields alone, even with no coal, would take the world beyond 1.5°C."[33]

3. *Increase royalties*. Following the example of Norway, federal and provincial governments should ensure a greater public return on fossil fuel extraction, and put aside funds to help the next generation or to aid adaptation and mitigation efforts in other parts of the world. Royalty reform could also include a price of carbon (reflecting what economists call the "social cost of carbon") at the wellhead. If all fossil fuel–producing countries took this initiative, it would expand coverage of carbon pricing globally, and provide higher revenues to compensate for reduced future extraction.

4. *Eliminate fossil fuel subsidies*. Unconventional oil and gas operations (fracking, drilling, mining) benefit from royalty credits and other subsidies. In the absence of these subsidies many marginal operations would be uneconomic, especially at the current low market prices. The International Institute for Sustainable Development estimates Canadian government subsidies at $3.3 billion per year.[34]

Canada must overcome its cognitive dissonance around the need for limits on extracted emissions going forward. The numbers in this report do not mean that fossil fuel exports would need to drop to zero immediately, but they highlight that it does not make sense to pursue policies that further increase extracted carbon. If all countries choose to act like Canada and continue to expand their extraction and export of fossil fuels, we are collectively giving up on limiting global warming to 1.5 to 2°C above pre-industrial levels. This is not the future envisioned in the Paris Agreement.

# Notes

**1** "The Canadian government has been "encouraging and cajoling" other countries on climate change," *Ottawa Citizen*, November 28, 2015, accessed December 19, 2016, http://ottawacitizen.com/storyline/the-canadian-government-has-been-encouraging-and-cajoling-other-countries-on-climate-change.

**2** Ashifa Kassam, "Canada approves controversial Kinder Morgan pipeline" in *The Guardian*, November 30, 2016, https://www.theguardian.com/world/2016/nov/29/canada-approves-kinder-morgan-oil-pipeline-justin-trudeau.

**3** The implications of the new Trump administration for the Paris Agreement are obviously significant, though there is much we do not know about the terms and process of a US withdrawal, or of the responses by other signatory countries. The Paris Agreement spans more than just one nation and presidency, and is designed to take effect over the course of several decades.

**4** United Nations Framework Convention on Climate Change, Paris Agreement, December 2015, https://unfccc.int/resource/docs/2015/cop21/eng/l09.pdf.

**5** UNEP (2016), *The Emissions Gap Report 2016*, November, http://uneplive.unep.org/media/docs/theme/13/Emissions_Gap_Report_2016.pdf

**6** Marc Lee, "A critical guide to the Pan-Canadian Framework on Clean Growth and Climate Change" in *Policy Note*, December 14, 2016, http://www.policynote.ca/a-critical-guide-to-the-pan-canadian-framework-on-clean-growth-and-climate-change/.

**7** This analysis draws on the framework presented in Steven J. Davis et al., "The Supply Chain of $CO_2$ Emissions" in *Proceedings of the National Academy of Sciences* 108, no. 45 (2011), 18554–59, www.pnas.org/cgi/doi/10.1073/pnas.1107409108. This global study develops estimates for all countries, but for only one year (2004); see its public dataset at https://supplychainco2.dge.carnegiescience.edu/data.html. Davis et al. use the terms *production emissions*, *consumption emissions* and *extraction emissions*, but these terms are not necessarily intuitive to readers. Extraction emissions can be easily confused with *emissions from fossil fuel extraction industries*, especially in the Canadian context. To provide greater clarity, this paper uses the terms *territorial emissions*, *carbon footprint* and *extracted carbon* respectively.

**8** Derived from published data in Kirsten S. Wiebe and Norihiko Yamano, *Estimating* $CO_2$ *Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015: Methodology and Results*, OECD Science, Technology and Industry Working Papers no. 2016/05 (Paris: OECD Publishing, 2016), http://dx.doi.org/10.1787/5jlrcm216xkl-en.

**9** http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/can-2016-nir-14apr16.zip

**10** National and Provincial/Territorial Greenhouse Gas Emission Tables, D — Canadian-Economic-Sector-Provinces-Territories, http://donnees.ec.gc.ca/data/substances/monitor/national-and-provincial-territorial-greenhouse-gas-emission-tables/D-Tables-Canadian-Economic-Sector-Provinces-Territories/?lang=en

**11** Intergovernmental Panel on Climate Change, *Synthesis Report 2014*, September 2014, Table 2.2, p 64, http://www.ipcc.ch/report/ar5/syr/.

**12** Higher number (80% unburnable) from J Leaton, *Unburnable Carbon: Are the world's financial markets carrying a carbon bubble?,* The Carbon Tracker Initiative, 2011, p. 2, http://www.carbontracker.org/carbonbubble. Lower number (66% unburnable) from International Energy Agency, *World Energy Outlook 2012*. http://www.iea.org/publications/freepublications/publication/English.pdf.

**13** For more detail in the context of oil and for a useful graphic, see "Petroleum Resources Classification System and Definitions" Society of Petroleum Engineers, accessed December 19, 2016, http://www.spe.org/industry/petroleum-resources-classification-system-definitions.php.

**14** For other estimates of plausible Canadian shares of a global carbon budget, including estimates based on population and GDP, see Marc Lee and Brock Ellis, *Canada's Carbon Liabilities: The Implications of Stranded Fossil Fuel Assets for Financial Markets and Pension Funds* (Ottawa: Canadian Centre for Policy Alternatives, 2013), https://www.policyalternatives.ca/publications/reports/canadas-carbon-liabilities. Another resource for understanding carbon budgets in light of the Paris Agreement is Simon Donner and Kirsten Zickfeld, *Canada's Contribution to Meeting the Temperature Limits in the Paris Climate Agreement*, unpublished, accessed December 19, 2016, http://blogs.ubc.ca/sdonner/files/2016/02/Donner-and-Zickfeld-Canada-and-the-Paris-Climate-Agreement.pdf.

**15** Overall share of reserves converts all categories to carbon dioxide equivalents. Calculated from production and reserves data from *BP Statistical Review of World Energy 2016*, (London: bp plc, 2016), http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html.

**16** Greg Muttitt, "The Sky's the Limit: Why the Paris climate goals require a managed decline of fossil fuel production," Oil Change International, September 22, 2016, http://priceofoil.org/2016/09/22/the-skys-limit-report/.

**17** Proven reserves estimated from *BP Statistical Review of World Energy 2016*. Proven plus probable reserves estimated in Marc Lee and Amanda Card, *Peddling Greenhouse Gases: What is the Carbon Footprint of Canada's Fossil Fuel Exports?* (Vancouver: Canadian Centre for Policy Alternatives, 2011), https://www.policyalternatives.ca/publications/reports/peddling-greenhouse-gases.

**18** Christophe McGlade and Paul Ekins, "The geographical distribution of fossil fuels unused when limiting global warming to 2°C," in *Nature* 517 (January 8, 2015), 187–90, http://www.nature.com/nature/journal/v517/n7533/full/nature14016.html. The percentages are slightly higher—88 per cent, 52 per cent and 35 per cent respectively—if carbon capture and storage (CCS) technology is not factored into the model. However, CCS does not make much difference in McGlade and Ekins modelling, as they project only to 2050 and they do not envisage much investment in CCS up to that point.

**19** To 2050 only, based on a 60 per cent chance of staying below 2°C.

**20** Peter Erickson et al., *Carbon Lock-In from Fossil Fuel Supply Infrastructure*, discussion brief (Seattle: Stockholm Environment Institute, 2015), https://www.sei-international.org/publications?pid=2805.

**21** National Energy Board, *Canada's Energy Future 2016: Update—Energy Supply and Demand Projections to 2040* (Ottawa: National Energy Board, October 2016), https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016updt/index-eng.html.

**22** In the original January 2016 document, the NEB estimates a "constrained" case of no pipelines. It also estimates a special "no LNG" case in which production stays roughly at 2016 levels and a "high LNG" case in which production is about 20 per cent higher than the reference case. Neither of these special cases is revisited in the October update.

**23** In the summer of 2015, Petronas revealed a "conditional final investment decision" after receiving a legislated commitment from the BC government to freeze its proposed tax and royalty rates as well as its regulatory regime. This announcement was mostly political, and a final investment decision is still pending.

**24** Marc Lee, "The abysmal economics of LNG," *Policy Note*, September 26, 2016, http://www.policynote.ca/the-abysmal-economics-of-lng/.

**25** Estimates of 1.44 units of raw gas produced at the wellhead to produce one unit of gas exported, from David Hughes, *A Clear Look at BC LNG: Energy security, environmental implications and economic potential* (Vancouver: Canadian Centre for Policy Alternatives, 2015), https://www.policyalternatives.ca/publications/reports/clear-look-bc-lng. For Woodfibre, the estimate is only 1.1 units of raw gas per unit of LNG exported because the plant has committed to using grid electricity for its operations.

**26** Higher estimates from Robert W. Howarth, "A Bridge to Nowhere: Methane Emissions and the Greenhouse Gas Footprint of Natural Gas" in *Energy Science & Engineering* (New York: John Wiley & Sons, 2014), http://www.eeb.cornell.edu/howarth/publications/Howarth_2014_ESE_methane_emissions.pdf. A summary paper from the Sustainable Gas Institute in the UK puts most estimates in the range of 0.5 to 3 per cent. Paul Balcombe et al., *Methane & $CO_2$ Emissions from the Natural Gas Supply Chain*, White Paper 1 (London: Sustainable Gas Institute, 2015), http://www.sustainablegasinstitute.org/wp-content/uploads/2015/09/SGI_White_Paper_methane-and-CO2-emissions_WEB-FINAL.pdf?noredirect=1.

**27** Hughes, note 25.

**28** Obama also rejected economic arguments made in favour of the pipeline and declared it was "not in the national interest." "Statement by the President on the Keystone XL Pipeline," press release from the White House, November 6, 2015, accessed December 19, 2016, https://www.whitehouse.gov/the-press-office/2015/11/06/statement-president-keystone-xl-pipeline.

**29** Note that oil sands production could also continue to increase in the absence of new pipeline capacity, through transport by rail. Thus, the broader issue is the commitment of industry and governments to continue to increase oil sands production (extracted carbon). Pipelines are indicative of the infrastructure needed to facilitate that growth, with a view toward developing export markets other than the US. For incremental production from new developments to be economical, oil prices would need to rise well above their current levels.

**30** Richard K. Lattanzio, *Canadian Oil Sands: Life-Cycle Assessments of Greenhouse Gas Emissions*, Congressional Research Service Report, R42537, March 10, 2014, accessed December 19, 2016, https://www.fas.org/sgp/crs/misc/R42537.pdf.

**31** Hans-Werner Sinn, *The Green Paradox: A Supply -Side Approach to Global Warming* (Cambridge, MA: MIT Press, 2012), p. xii.

**32** See the framework in Michael Lazarus et al., *Supply-Side Climate Policy: The Road Less Taken*, working paper 2015-13 (Seattle: Stockholm Environment Institute, 2015), https://www.sei-international.org/publications?pid=2835.

**33** Oil Change International, "The Sky's the Limit."

**34** International Institute for Sustainable Development, "G20 Subsidies to Oil, Gas and Coal Production: Canada," November 2015, accessed December 19, 2016, http://www.iisd.org/library/g20-subsidies-oil-gas-and-coal-production-canada.