The oilsands in a carbon-constrained Canada

The collision course between overall emissions and national climate commitments

Benjamin Israel

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Production management: Michelle Bartleman
Editors: Michelle Bartleman, Roberta Franchuk, Sarah MacWhirter
Contributors: Nichole Dusyk, Simon Dyer, Duncan Kenyon, Morrigan Simpson-Marran

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The Pembina Institute
219 19 Street NW
Calgary, AB
Canada T2N 2H9
Phone: 403-269-3344

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About the Pembina Institute

The Pembina Institute is a national non-partisan think tank that advocates for strong, effective policies to support Canada's clean energy transition. We employ multi-faceted and highly collaborative approaches to change. Producing credible, evidence-based research and analysis, we consult directly with organizations to design and implement clean energy solutions, and convene diverse sets of stakeholders to identify and move toward common solutions.

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The Pembina Institute would like to sincerely thank those who provided us feedback and expert advice during the development of this report. We appreciate the generosity of their time and effort, their thoughtful comments and critiques, and their willingness to engage in this challenging but important discussion.

We would also like to dedicate this report to the memory of our former colleague and friend Jodi McNeill — a passionate advocate of the environment, a bright and independent spirit, a bridge-builder in an increasingly polarized environment — whom we deeply miss.

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Foreword

Simon Dyer
Executive Director

The Pembina Institute is a non-partisan, evidence-based, national research organization, founded in central Alberta as a response to the Lodgepole sour gas blowout in 1982. For more than 30 years, we have collaborated with oil and gas companies, communities, stakeholders, and all levels of government from across the political spectrum to find practical solutions for shared energy issues.

Our long record of working with the oilsands industry, assessing its impacts on Alberta's environment and communities, as well as on Canada's greenhouse gas emissions overall, have helped form policies that have led to significant environmental improvements.

In 2006, the Pembina Institute identified the need for and mapped out a pathway to carbon-neutral oilsands — a goal which many years later is now being embraced by oilsands companies.

For more than 30 years, we have collaborated … to find practical solutions for shared energy issues.

We helped develop the regulatory framework for carbon capture and storage project development in Alberta, and helped to pioneer environmental, social and governance performance indicators for oilsands operators through company-specific environmental performance report cards. In 2015, we worked with leading oilsands companies and other environmental organizations to make recommendations for Alberta's Climate Leadership Plan, which included an industry-wide benchmark on carbon intensity, a 100-megatonne annual limit on oilsands emissions, and ambitious methane reduction targets.

Our record and expertise on oilsands issues is strong. We have worked tirelessly to ensure fossil fuel development is in the public interest, to protect people, conserve ecosystems, and tackle the global problem of climate change that is already exacting punishing costs on Canadians. The need to carefully map out a sustainable economic future in a decarbonized world is too urgent and the global problem of climate change is too complex for any of us to solve alone.

The need to carefully map out a sustainable economic future in a decarbonized world is too urgent and the global problem of climate change is too complex for any of us to solve alone.

We urgently need to work together to prepare Canada for the 21st-century, decarbonized economy and have a fact-based discussion about the role of the oilsands. This is a hard conversation that we as Canadians need to have in a constructive and thoughtful way — let's not shy away from it.

Simon Dyer, Executive Director

Executive summary

Alberta's oilsands are at a crossroads.

The oil and gas industry has made big contributions to Canadian society: providing jobs, technology and research excellence, while warming homes, fuelling cars and powering our electricity grids. Today, the oil and gas sector is facing unprecedented pressures. While dramatic fluctuations in the price of energy commodities are not new, increasing automation, adoption of new disruptive technologies, shifting market demands, and climate commitments are reshaping the future of this sector. Business-as-usual no longer applies — significant changes are necessary.

In a continuing effort to depolarize the conversation, this report seeks to help establish a basic, commonly agreed-upon set of facts about Alberta's oilsands, their emissions performance and trajectories, and what Canada's commitment to achieve deep decarbonization will mean for the sector. Key points:

- **Carbon emissions from the oilsands sector are the fastest-growing source of emissions in Canada**. This continuing upward trajectory not only reduces the country's ability to meet its 2030 reduction commitments, but is on a clear collision course with Canada's plan to become carbon-neutral by 2050. (Figure 1)
- **Oilsands products are not homogeneous and there is a wide range in performance** when it comes to carbon emissions intensity. As a result of variations in bitumen quality and extraction technologies, the range between the highest and lowest upstream emissions intensity per barrel is nearly threefold.
- **The oilsands industry has worked toward decreasing the emissions intensity of its products in the past decades.** Continuous improvements have reduced the carbon intensity of specific oilsands products, ranging from a 4% to 21% reduction since 2009.
- Despite these improvements in carbon intensity, ***absolute* carbon emissions from the oilsands continue to increase overall**, as growth in production outpaces gains from reductions in per-barrel intensity.

- **Studies reviewed for this report consistently find oilsands products to be more carbon intensive than lighter, conventional oil sources.** Recognizing limitations of emissions intensity research and the challenge of comparing studies, the best estimate currently available suggests a barrel of oil produced in Canada is associated on average with 70% more GHG emissions than the average crude produced globally.
- Acknowledging oil demand will not disappear overnight, most outlooks predict demand will plateau or decline within the next decade. Subsequent **global shifts toward lower-intensity energy options are likely to put more carbon-intense crudes** — such as the bulk of oilsands products — **at risk** over the next decade.
- **The rapid development and deployment of breakthrough technologies** — as opposed to incremental improvements — **is needed** for the sector to decrease its *absolute* carbon emissions in line with our climate commitments, and to remain competitive as global energy systems change.

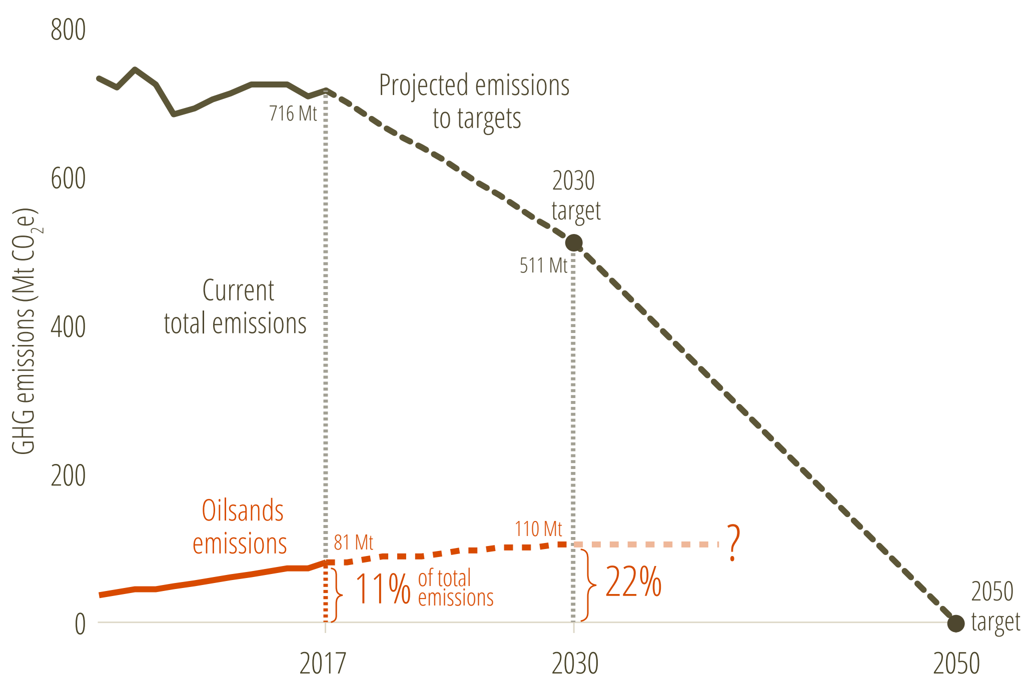

Figure 1. Share of the oilsands emissions in national carbon budget to meet Canada's 2030 target

Data source: ECCC

Note: See Figure 6 for additional details.

Recognizing the improvements that the oilsands industry has made to date and the commitments leading companies have announced to achieve ambitious targets in the future, there is still a need for the sector to embrace its responsibility to reduce overall carbon emissions in accordance with Canada's 2030 and 2050 targets.

The Pembina Institute calls for both the Alberta and federal government to recognize the willingness of leading companies to adopt aggressive decarbonization targets, as well as mounting investor pressure to decarbonize the sector, and implement policies that will drive toward carbon-neutral — or even carbon-negative — oilsands production.

It's time to have a national conversation about how to reconcile oilsands emissions with Canada's goal to decarbonize its economy by 2050. The intention of this report, carefully and explicitly supported by available evidence and research, is to further fact-based dialogue, as we all embark on this tough, but necessary Canadian conversation.

Recommendations to improve oilsands climate performance

1. Establish strong regulations to decarbonize the industry

Intentional effort is required to encourage a shift toward low- and zero-carbon production, by creating strong incentives for the development and deployment of breakthrough innovation. Recognizing the willingness of leading companies to adopt aggressive decarbonization targets, as well as mounting investor pressure to decarbonize the sector, governments need to implement policies that will drive carbon-neutral — or even carbon-negative — oilsands production.

2. Define and enforce sector emissions targets for 2030 and 2050, with five-year increments

Meeting our 2030 and 2050 climate targets will require all sectors of our economy — and all Canadians — to do their fair share to contribute to the global effort of limiting the average temperature increase to 1.5°C. Decreasing GHG emissions reduction targets need to be set for the oil and gas sector, in five-year increments that would allow Canada to meet its 2030 national objective and its pledge to become a net-zero carbon emitter by 2050.

3. Support an innovation ecosystem to deliver breakthrough technologies

A robust ecosystem to support innovation, research and development, needs to be funded and fostered so it can deploy solutions aimed at delivering breakthrough reductions — beyond incremental improvements — in emissions of current oilsands projects, as well as non-combustion uses of Alberta's oil and gas resources.

4. Improve emissions monitoring and reporting

Existing measurement, monitoring and reporting processes for oilsands emissions must be reviewed, strengthened and standardized in order to produce coherent data and enhance the transparency of the sector. As well, further analysis looking at existing and upcoming technology pathways is required to better situate oilsands products' carbon intensity on the global supply curve.

5. Appoint credible and effective energy regulators

Effective energy regulators are needed both provincially and federally. They must be transparent and independent, with the ability to incorporate robust environmental and climate considerations into their decision-making, while having both the mandate to enforce regulations and the capacity to follow through on that enforcement.

1. Introduction

The oil and gas industry has made a big contribution to Canadian society. It has provided jobs, technology and research excellence, while warming our homes, fuelling our cars and powering our electricity grids. However, things are changing. Climate change, while costing Canadians billions annually,[1] is also leading toward planetary tipping points.[2] The oil and gas sector is already being impacted by increasing automation, adoption of new disruptive technologies, shifting market demands — including for increasingly decarbonized energy sources — and dramatic fluctuations in the price of energy commodities.

Beyond a national commitment to cut emission by 30% by 2030, the current federal government has promised to take Canada to net-zero carbon emissions by 2050.[3] That means considerable changes for Canada's oil and gas industry — and Alberta's oilsands in particular.

As Albertans face the challenge of finding their place in this emerging new economy, statements about the province's energy resources — often conflicting ones — are splashed across news sites, opinion pages, press releases, social media and even T-shirts. In a politically fractured country and an increasingly decarbonizing global economy, making heads or tails of specific statements in the deluge of information has become more important than ever, not just for energy analysts or policy wonks, but for those whose jobs and livelihoods depend on it, and for all of us concerned about the catastrophic impacts of climate change here in Canada and around the world.

It has become increasingly common to hear Canada's oil described by supporters as "the cleanest, most ethical, environmentally-friendly energy in the world."[4] There are many ways to assess the performance of Alberta's oilsands, and it is true that many oil-

[1] While no official data is currently available, the liabilities of the Disaster Financial Assistance Arrangements (DFAA), gives an indication of the financial impacts of climate change, increasing from around $100 million per year in the 1990s to $500 million in 2009-10, and reaching $2 billion in 2013-14 and $1.6 billion in 2014-15. This metric is likely conservative as it focuses on only one of the ways climate change impacts our society (i.e. extreme weather events). Office of the Parliamentary Budget Officer, *Estimate of the Average Annual Cost for Disaster Financial Assistance Arrangements due to Weather Events*, February 2016. https://www.pbo-dpb.gc.ca/web/default/files/Documents/Reports/2016/DFAA/DFAA_EN.pdf

[2] Intergovernmental Panel on Climate Change, "Global Warming of 1.5 °C." https://www.ipcc.ch/sr15/

[3] Although it is Canada's new climate target for 2050, as of February 2020, there is no official definition for what "net-zero" carbon emissions mean. In this report "net-zero" and "carbon-neutral" are used interchangeably.

[4] Andrew Scheer, Twitter post, August 30, 2018, 9:02 a.m. https://twitter.com/AndrewScheer/status/1035196080361811968

producing nations don't measure up to Canada's democratic and regulatory models, as well as its environmental, social and governance (ESG) standards. However, to ignore or misrepresent legitimate challenges facing the climate performance of the oilsands industry is not a strategy that will help the industry succeed.

As a clean energy think tank with specific expertise in responsible fossil fuel development, the Pembina Institute has historically focused on a wide range environmental impacts of the oilsands: the adverse effects on surface and underground water, air quality, wildlife and surrounding ecosystems, and the challenges of tailings ponds and greenhouse gas emissions. [5] Increasingly our work encompasses the economic risk and financial liabilities related to oilsands activities.

This report, however, is focused specifically on the question of oilsands' carbon performance, its impacts on national climate change commitments, and what Canada's deep decarbonization means for the industry. Given that absolute carbon emissions in Canada and elsewhere have to decrease at an accelerating pace, Alberta's increasing oilsands emissions are accounting for a growing share of the pie.

Canada's oilsands: a primer

Canada has the third-largest oil reserves in the world with 167 billion barrels of crude oil; 96% of these reserves are found in the oilsands of northern Alberta.[6] The oilsands are the fastest-growing source of Canadian oil, producing about 2.9 million barrels per day (MMb/d) in 2018 (Table 1). By 2040, the federal government expects oilsands production is to reach just under 4.5 MMb/d — a 55% increase.[7]

The bitumen extracted from the oilsands, whether through open pit mining or in situ recovery, is a thick, sticky and viscous form of crude oil, characterized by the industry as extra-heavy oil.[8] Unlike light crude oil, bitumen needs to be treated in order to flow on its own.

Bitumen accessible by mining comprises about 19% of oilsands reserves; however, in 2018 it accounted for almost half of oilsands extraction. The other 81% of Alberta's

[5] Pembina Institute, *Solving the Puzzle: Environmental responsibility in oilsands development* (2011). https://www.pembina.org/pub/2210. *Beneath the Surface: A review of key facts in the oilsands debate* (2013). https://www.pembina.org/pub/2404

[6] Natural Resources Canada, "Crude oil facts: Canadian resources." https://www.nrcan.gc.ca/crude-oil-facts/20064

[7] Canada Energy Regulator, *Canada's Energy Futures 2018 Supplement: Oil Sands Production* (2018). https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2018lsnds/index-eng.html

[8] Raw bitumen generally has an API gravity below 10°, which makes it an extra-heavy crude oil. When this bitumen is diluted to meet pipeline specifications, it becomes dilbit, with an API gravity corresponding to that of heavy oil. In other words, oilsands bitumen is extra-heavy oil, but its marketable products are either heavy oil (e.g. dilbit) or light oil (e.g. synthetic crude oil).

oilsands are too deep to be accessed from an open pit mine and can only be extracted through in situ — or "in place" — methods.[9]

Because bitumen can't naturally flow through a pipeline, it is converted into marketable products either by diluting or upgrading before being sent for refining. Diluted bitumen, or dilbit, can only be processed in high conversion refineries, specifically equipped to work with heavy crude oils, while bitumen upgraded into a synthetic crude oil (SCO), which has characteristics similar to lighter sweet crude oils, can theoretically be processed by most refineries.

Mined bitumen has historically been upgraded because high levels of impurities (e.g. asphaltenes) prevent it from meeting pipeline specifications even when diluted. Meanwhile bitumen extracted in situ, which contains fewer impurities, has traditionally been diluted.

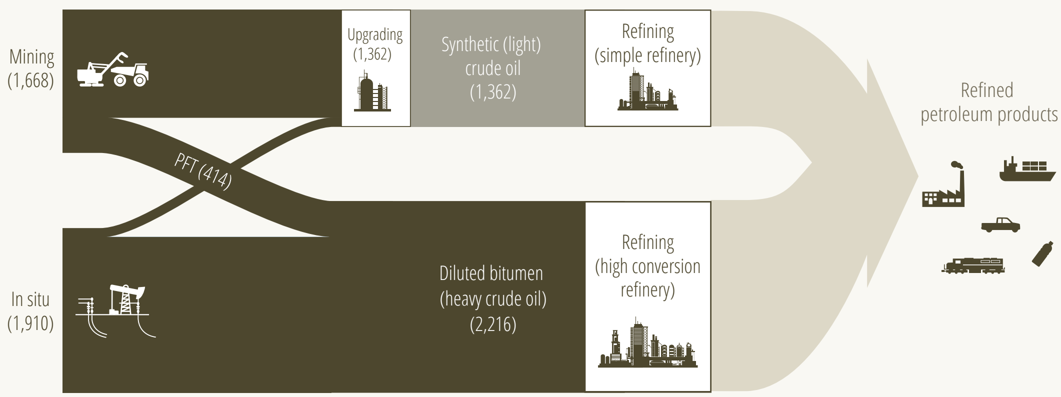

Figure 2. Capacity of existing oilsands pathways (thousand barrels per day)

Data source: Oil Sands Magazine[10]

The two main pathways used to convert oilsands bitumen into refined petroleum products (Figure 2) require more energy-intensive processing than most conventional oils, which translates into additional carbon emissions at one stage or another. Diluted bitumen is a heavy crude oil with a high sulphur content, and thus requires more processing than lighter crudes to be transformed into transportation fuels. Meanwhile, upgrading involves energy-intensive processes, and is generally associated with more carbon pollution on a per-barrel basis than refining straight bitumen. Paraffinic froth treatment (PFT), however, is a relatively new technology that has opened a new

[9] "Crude oil facts."

[10] Oil Sands Magazine, "Mining Operations"; "Thermal In-Situ Facilities"; "Bitumen and Heavy Oil Upgraders." Consulted on November 15, 2019. https://www.oilsandsmagazine.com/projects

"technology pathway" whereby mined bitumen can be diluted to meet pipeline standards.[11] In 2018, 43% of raw bitumen from the province's oilsands was sent for upgrading in Alberta,[12] but this proportion is expected to decrease in coming years due to fixed upgrading capacity combined with growth of in situ production.

Table 1. Global and Canadian oil production in 2018

Metric	Amount
Canada's total crude oil reserves[12]	167 billion barrels
Canada's total oilsands reserves[12]	161 billion barrels
Oil produced globally[13]	101 MMb/d
Oil produced in Canada[12]	4.6 MMb/d
Canadian oil exported — total[12]	3.7 MMb/d
To the United States	*3.5 MMb/d*
Oil imported — total[14]	0.6 MMb/d
From the United States	*0.4 MMb/d*
From Saudi Arabia	*0.1 MMb/d*
From other countries[15]	*0.1 MMb/d*
Oil produced by Canadian oilsands (64% of national production)[12]	2.9 MMb/d
Canadian refining capacity (at 16 refineries)[16]	1.9 MMb/d
Canadian upgrading capacity[12]	1.3 MMb/d

[11] The PFT technology drastically reduces impurities, such as asphaltenes, contained in mined bitumen, allowing it to be diluted to meet pipeline specifications — therefore removing the requirement of upgrading.

[12] "Crude oil facts."

[13] U.S. Energy Information Administration, *Short-Term Energy Outlook,* "Forecasts: Global liquid fuels.". https://www.eia.gov/outlooks/steo/report/global_oil.php. This production includes condensates (also referred to as natural gas liquids) which can be processed in a refinery.

[14] Statistics Canada, *Canadian International Merchandise Trade Database*, Table 990-0027 27. Imports; Trade commodity: 270900 Petroleum oils and oils, obtained from bituminous minerals, crude. https://www5.statcan.gc.ca/cimt-cicm/topNCountries pays?lang=eng&refYr=2018&refMonth=1&freq=12&provId=1&retrieve=Retrieve&tradeType=3&topNDefault=250&chapterId=27&arrayId=0&sectionLabel=V%20%20Produits%20min%20raux&commodityId=270900

[15] Other import sources in 2018 included Azerbaijan, Norway, Nigeria, United Kingdom, Algeria, Colombia, Ivory Coast, Russian Federation and Libya.

[16] *National Energy Board, Canadian Refinery Overview: Energy Market Assessment* (2018). https://www.cer-rec.gc.ca/nrg/sttstc/crdlndptrlmprdct/rprt/2018rfnryrprt/2018cndnrfnrvrvw-eng.pdf

2. The oilsands in context

2.1. Canada's annual emissions by sector

Canada's greenhouse gas (GHG) emissions[17] — a total of 716 Mt CO_2e in 2017 according to the latest available data[18] — are generated by several main economic sectors: oil and gas, transportation, heavy industry and manufacturing, buildings, electricity, agriculture and waste.

The oil and gas sector is responsible for more than a quarter of Canada's total emissions (195 Mt CO_2e in 2017), primarily from burning natural gas to create heat for extracting and processing oil, but also from producing on-site electricity to power operations; from venting, flaring and fugitive emissions; and from fuels to run vehicles (Figure 3).

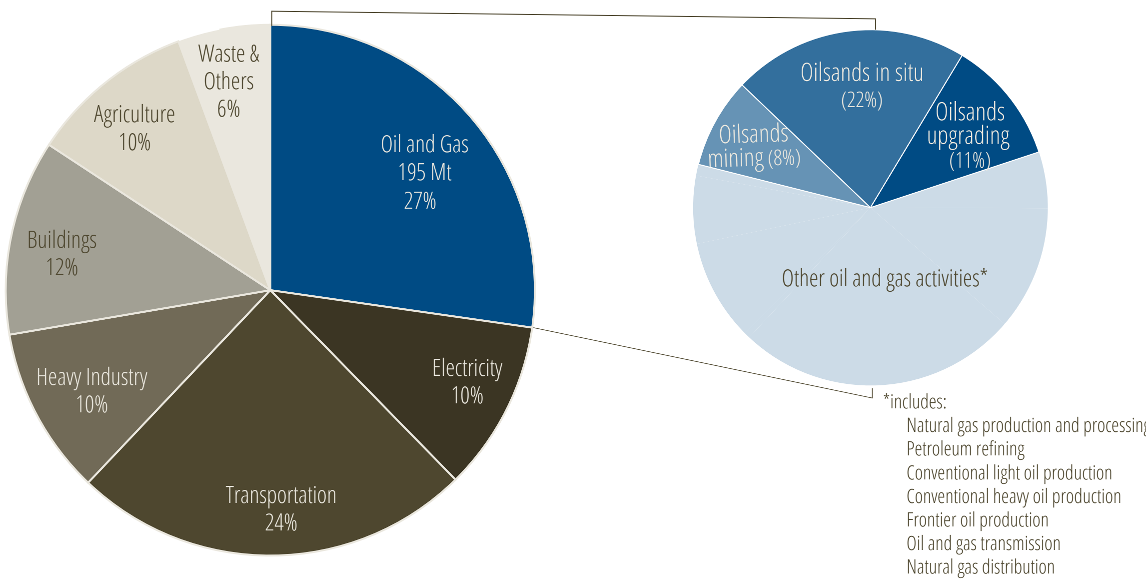

Figure 3. Breakdown of emissions associated with oil and gas extraction and processing in Canada in 2017

Data source: Environment and Climate Change Canada (ECCC)[19]

Note: Other industries grouped with waste include coal production as well as light manufacturing, construction and forest resources.

[17] Greenhouse gas (GHG) emissions are usually measured in megatonnes (Mt) of carbon dioxide (CO_2) equivalent (CO_2e). One metric tonne is 1,000 kg; one megatonne (a million tonnes) is one billion kilograms of CO_2. Unless otherwise specified in this report, GHG emissions, carbon emissions, carbon pollution and emissions are used interchangeably.

[18] Environment and Climate Change Canada, *2019 National Inventory Report 1990–2017: Greenhouse Gas Sources and Sinks in Canada*, Part 3, Table A10-2. https://unfccc.int/documents/194925

[19] *Ibid*.

Within the oil and gas sector, the largest share of GHG emissions comes from the extraction and processing of bitumen from the oilsands — a total of 81 Mt CO_2e for mining, in situ and upgrading.[20] The oilsands, therefore, accounted for 11% of Canada's total emissions in 2017.

Accounting for electricity emissions

There are different ways to look at the oilsands' GHG emissions. The approach used by Environment and Climate Change Canada (ECCC), which are consistent with reporting methods established by the United Nations Framework Convention on Climate Change, accounts for direct emissions from the sector. These include emissions from electricity generated at oilsands facilities (through a process called cogeneration) and exported to the provincial grid.

Sometimes, however, cogenerated electricity is not included when calculating emissions. In this case, overall oilsands production emissions will be slightly lower than those reported by ECCC.

An alternate approach is to exclude emissions from electricity exported to the grid, while including those emissions from electricity purchased to run the plant. This approach allows for an even more precise assessment of emissions from actual oilsands operations.

Finally, certain analyses expand the scope and account for emissions associated with all energy types (e.g. steam, hydrogen) entering or leaving the plant, or other indirect emissions (e.g. production of natural gas and diluent used at the plant, emissions from land use changes).

Studies using these various approaches are discussed further in Section 3.

[20] Of those 81 Mt, approximately 78 Mt are associated with oilsands production occurring in Alberta, and approximately 3 Mt in Saskatchewan.

2.2. Canada's annual emissions by province

Emissions from Alberta alone account for more than a third (273 Mt CO_2e) of Canada's total GHGs[21] and those from Alberta's oil and gas sector (19% of Canada's overall emissions) are the largest single source of emissions across Canada (Figure 4).

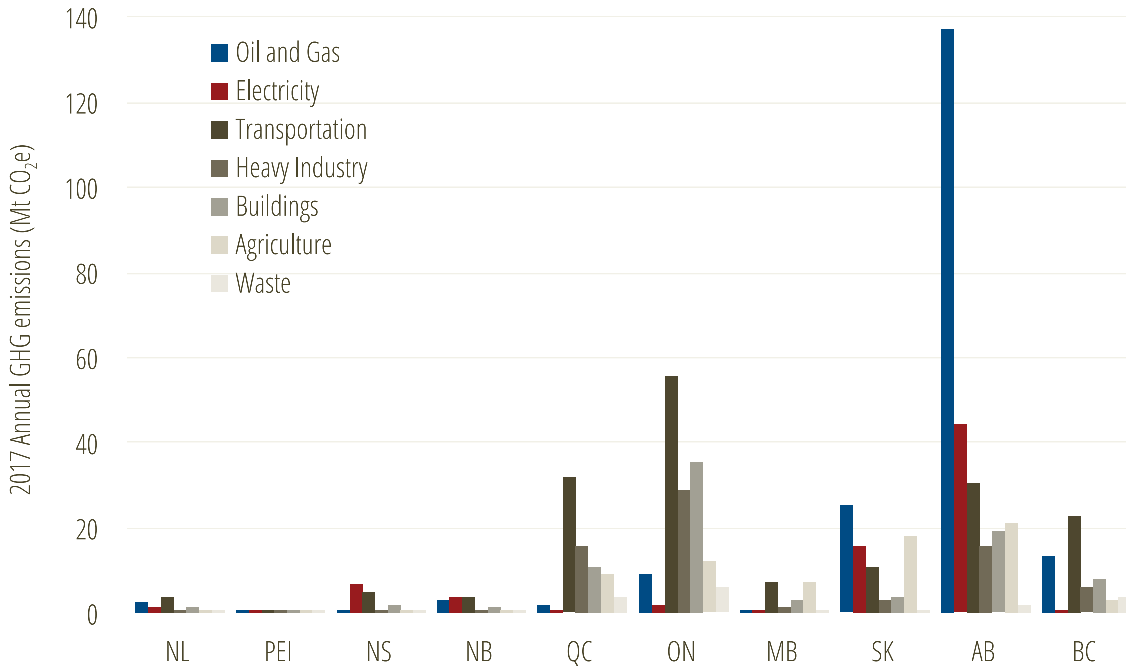

Figure 4. Provincial GHG emissions by sector in 2017

Data source: ECCC[22]

[21] *2019 National Inventory Report,* Part 3, Table A11–19.

[22] *Ibid.,* Tables 11–2 to 11–21.

2.3. Our international commitments

In the last decade, Canada has signalled its intention to drastically reduce its carbon pollution through a number of pledges and international commitments:

- **Copenhagen Agreement (2009)** — set a target of reducing GHGs by 17% by 2020 (to 606 Mt CO_2e), from 2005 levels.
- **Paris Agreement (2015)** — committed to reducing emissions by 30% by 2030 from 2005 levels (to 511 Mt CO_2e).
- **Canada's mid-century goals (2016)** — a national strategy (Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy) to achieve an 80% emissions reduction (to 146 Mt CO_2e) by 2050 from 2005 levels.[23]
- **Carbon Neutrality Coalition (2018)** — Canada joined this international group of nations with intentions to become carbon-neutral.[24] In Fall 2019, the current federal government promised to meet this objective by 2050.

Historically, Canada has struggled to deliver on its reduction commitments. The 2020 Copenhagen emissions target is out of reach, and a recent report from Environment and Climate Change Canada (ECCC) shows the country is not on track to achieve the 2030 emissions reduction target as per the Paris Agreement.[25]

Regardless, Canada continues to work toward further and further decarbonization, and as it does, the Alberta oilsands' increasing share of emissions becomes more prominent.

[23] Government of Canada, *Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy* (2016). https://unfccc.int/files/focus/long-term_strategies/application/pdf/canadas_mid-century_long-term_strategy.pdf

[24] "Carbon Neutrality Coalition." https://www.carbon-neutrality.global

[25] Environment and Climate Change Canada, *Canada's fourth biennial report on climate change*, 28. https://unfccc.int/sites/default/files/resource/Canada%E2%80%99s%20Fourth%20Biennial%20Report%20on%20Climate%20Change%202019.pdf

2.4. Projecting oilsands emissions

The oilsands have historically been the fastest growing source of carbon emissions in Canada — and are expected to remain so in the near future.

While emissions from the entire oil and gas sector — including oilsands — increased by 23% between 2005 and 2017, those from the oilsands alone have more than doubled and are projected to keep growing at a similar pace through to 2030 (Figure 5).[26]

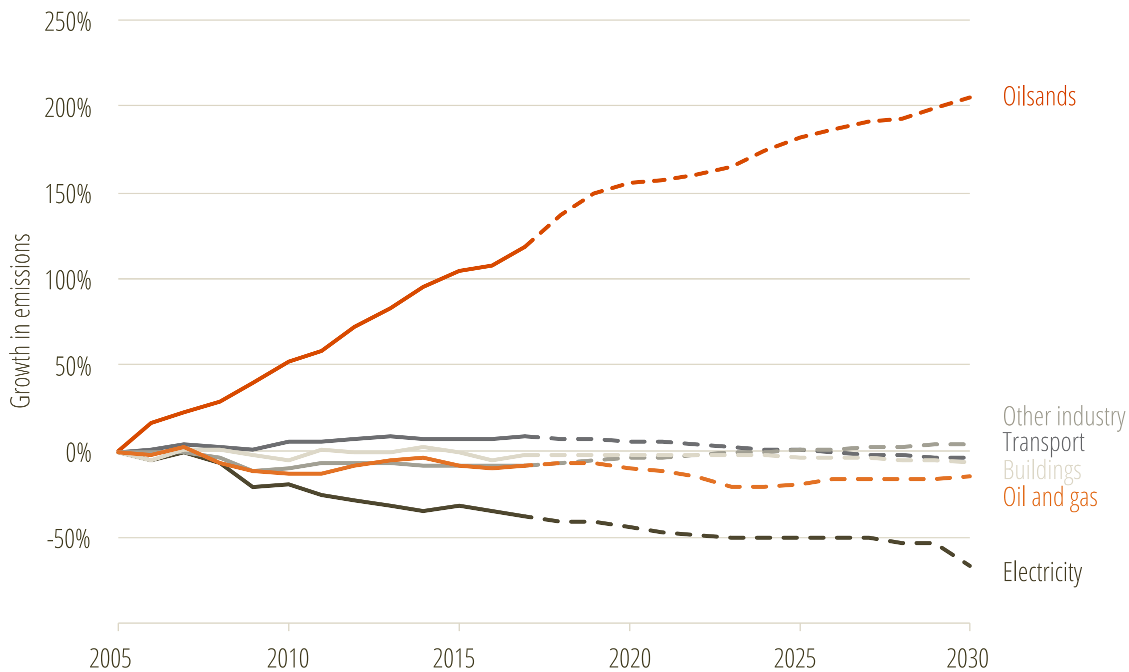

Figure 5. Historic and projected emissions growth by Canadian economic sectors

Data source: ECCC[27]

Note: "Oil and gas" represents the emissions of the sector excluding that of the oilsands, which are represented separately, while "Other industry" includes heavy industry, agriculture, waste and others. This chart represents the annual growth rate in emissions of Canada's economic sectors relative to the year 2005, the reference year for Canada's climate commitments. Annual growth rate should not be confused with absolute emissions.

Based on the federal government's projections,[28] as of 2030, absolute emissions from the oilsands would account for 110 Mt CO_2e, or 22% of Canada's total climate target (511 Mt CO_2e) (Figure 6).

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[26] Environment and Climate Change Canada, *Canada's GHG and Air Pollutant Emissions Projections 2018*, 18. https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/projections-2018.html

[27] *Canada's GHG and Air Pollutant Emissions Projections 2018*.

[28] *Canada's fourth biennal report on climate change*, 118.

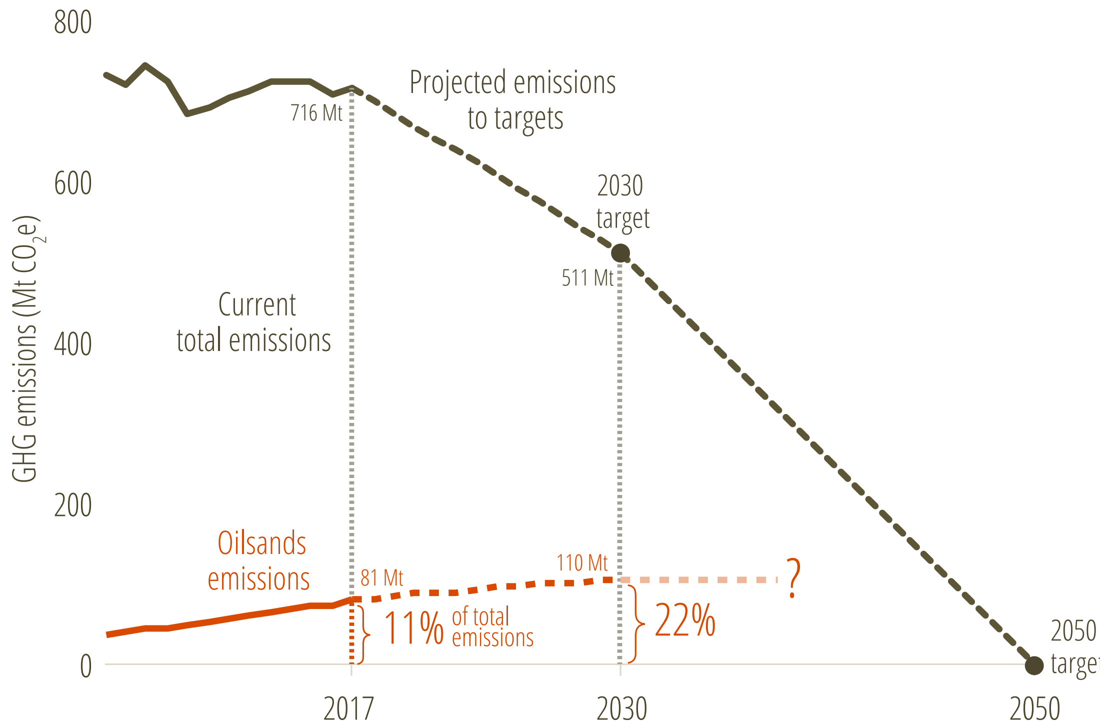


Figure 6. Share of the oilsands emissions in national carbon budget to meet Canada's 2030 target

Data source: ECCC[29]

Note: Canada's overall emissions between 2017 and 2030 are estimated based on the annual emissions reductions required to meet the 2030 emissions target. ECCC indicates that oilsands will emit 110 Mt in 2030, which includes approximately 100 Mt of emissions under Alberta's oilsands emissions limit, plus emissions exempt from the limit as discussed in the following section (Oilsands emissions limit).

While there are no governmental projections for Canada's emissions past 2030, delivering our 2050 commitment requires the absolute emissions of Alberta's oilsands to peak and begin to decline on a pathway toward becoming carbon-neutral — if not carbon-negative — well before 2050.

Oilsands emissions limit

In 2016, the Government of Alberta passed the Oil Sands Emissions Limit Act, which establishes a firm limit for oilsands emissions.[30] It caps emissions associated with oilsands extraction and upgrading at 100 Mt CO_2e per year, with an additional 10 Mt CO_2e provision for newly built upgraders.

[29] *Canada's fourth biennal report on climate change.*

[30] Government of Alberta, *Oil Sands Emissions Limit Act*, R.S. 2016, c. O-7.5. http://www.qp.alberta.ca/documents/Acts/O07p5.pdf

By putting a hard limit on the carbon emissions — rather than production — of the oilsands, the act aims to encourage innovation in technologies that can drastically cut the oilsands' emissions intensity, allowing the sector to increase production if emissions stay under the limit. Relevant regulations, as prescribed by the act, had not been created as of February 2020, meaning the limit could not yet be enforced were the industry to approach or surpass the 100 Mt limit.[31]

The act specifically exempts certain types of oil production and activities from the oilsands emissions limit. Such exemptions include emissions from cogeneration, from primary oil production, and from oil produced through enhanced recovery techniques and experimental schemes. In addition, because the act is a provincial regulation of Alberta, it does not apply to oilsands activities occurring in Saskatchewan. For those reasons, of the 94 Mt oilsands emissions estimated by the federal government in 2020, approximately 82 Mt would be subject to the 100 Mt limit (Table 2).

Table 2. Projected oilsands emissions in 2020[32]

Metric	2020
Total oilsands emissions (Mt)	94.5
Emissions included in the oilsands limit (Mt)	84.2
Total emissions exempt from the oilsands limit (Mt)	10.3
Cogeneration	*4.4*
Primary production	*2.3*
Saskatchewan's production	*2.6*
New upgrading capacity (up to 10 Mt)	*1.0*

Source: ECCC [33, 34, 35]

Note: Emissions from Saskatchewan's oilsands production are estimates using 2017 data.

As of December 2019, the Alberta Energy Regulator (AER) has approved projects with cumulative emissions totalling 147 Mt CO_2e, presuming all projects proceed using existing production techniques. This figure rises to 173 Mt CO_2e when including projects currently seeking approval by the Alberta Energy Regulator.[36]

[31] As of February 2020, relevant regulations as per Section 3 of the act have not yet been defined.

[32] This table was updated with new data obtained from ECCC in the March 2020 version of this report.

[33] *Canada's fourth biennal report on climate change*, 118.

[34] *2019 National Inventory Report.*

[35] A detailed breakdown of projected oilsands emissions in 2020 was obtained from ECCC.

[36] Methodology notes for this analysis are available in Appendix B.

Given that the legislation was never implemented through regulation, and Canada's climate targets call for decarbonization of the oilsands industry, the conversation needs to move beyond a ceiling for emissions of 100 Mt.

2.5. Projecting global oil demand

While demand for oil has increased at a fast pace over the past decades, this trend is likely to change in the next decade. A number of projections developed over the past couple of years anticipate that demand for oil will plateau or start declining in the next five to 15 years (Figure 7).[37]

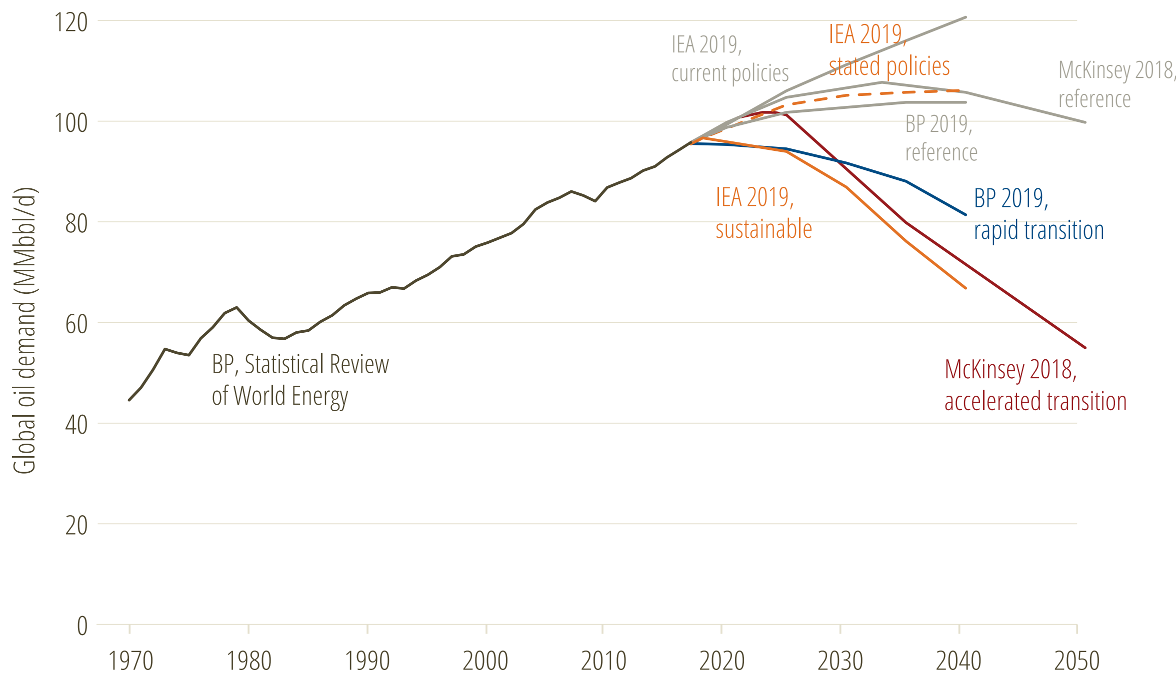


Figure 7. Comparison of oil demand scenarios from the IEA, BP and McKinsey

Data sources: IEA,[38] BP,[39,40] McKinsey[41]

[37] Such projections should not be considered as forecasts. Rather, as noted in the 2019 IEA Energy Outlook, they are scenarios aimed at "exploring various possible futures, the ways that they come about, the consequences of different choices and some of the key uncertainties."

[38] International Energy Agency, "World Energy Outlook 2019." https://www.iea.org/weo2019/

[39] BP, "Statistical Review of World Energy." https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[40] BP, "BP Energy Outlook." https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html

[41] McKinsey & Company, "Global Energy Perspective: Accelerated Transition," *Energy Insights*. https://www.mckinsey.com/industries/oil-and-gas/how-we-help-clients/energy-insights/global-energy-perspective-accelerated-transition

One notable exception is the 2019 outlook of the International Energy Agency (IEA), whose "Current Policy Scenario" predicts oil demand will keep increasing at the same pace as over the last decade. However, not only is this scenario *not* the central scenario in the IEA outlook, it would result in 4.1–4.8°C of global warming by the end of the century,[42] more than double the global warming limits explored in a 2019 report by the Intergovernmental Panel on Climate Change (IPCC).[43]

When accounting for forces that are contributing to reduced oil demand — for example, electrification of transport (e.g. electric vehicles), reduced plastics demand (e.g. ban on single-use plastics), efficiency gains and low-carbon fuels for aviation and marine sectors — the same sources predict oil demand growth will slow down and nearly plateau within five years.

This trend is further exacerbated when intentional action to protect the climate and environment is factored in. Of those scenarios, the "Stated Policies Scenario" — the IEA's new reference scenario reflecting the impact of existing and announced policies — represents the current trajectory and shows oil demand nearly plateauing in the 2030s, while limiting global warming to 2.7–3.2°C. In contrast, BP, McKinsey and IEA's transition scenarios project a rapid decline in oil demand starting in the early 2020s. IEA's "Sustainable Development Scenario" — the most ambitious of those scenarios — would allow for keeping global warming below 1.65°C.

Regardless of when the curve starts to bend, as demand for oil changes, factors like emissions intensity, driven by both investors and climate realities, will play an increasingly important role.

[42] Climate Action Tracker, "Temperatures." https://climateactiontracker.org/global/temperatures/

[43] Intergovernmental Panel on Climate Change, "Global Warming of 1.5 ºC."

3. Emissions intensity of oilsands

Emissions intensity is a metric being used widely to demonstrate the recent climate improvements of oilsands production. Carbon intensity measures the amount of GHGs emitted throughout a portion or all of the oil supply chain to produce either a given volume of crude oil or a given amount of energy from the oil product.[44] The emissions intensity is a useful metric for establishing and comparing the climate impacts of various crude oils. It should, however, not be confused with absolute emissions, which refers to the overall quantity of carbon actually emitted in the atmosphere.

3.1. Measuring emissions intensity

The carbon intensity of crude oils can be analyzed across different portions of the oil production process (Figure 8). While life cycle assessments (LCA) technically include the full process from land use through to combustion, analyses are often done for only portions of the chain.

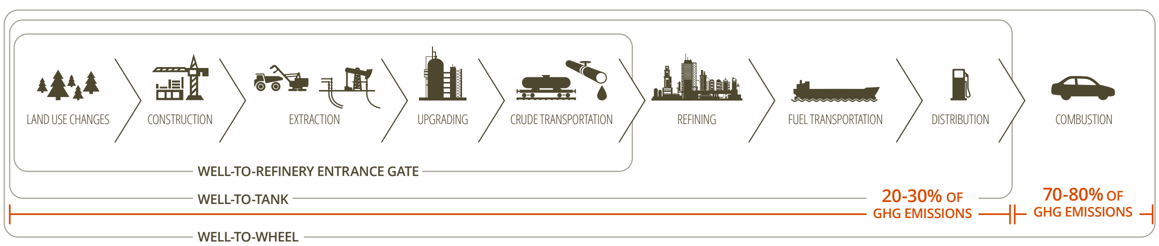


Figure 8. Scopes of life cycle GHG emissions from transportation fuels

Note: Some life cycle assessments do not include emissions associated with land use changes and construction, although its inclusion is deemed best practice. Also, as noted earlier in this report, not all bitumen is upgraded.

Well-to-refinery-gate (or upstream) life cycle analysis estimates emissions from extraction and processing only — including diluting and/or upgrading as well as transportation to the refinery — but doesn't include refining. The well-to-tank analysis assesses emissions from extraction through to the delivery of a transportation fuel to the tank of a vehicle, but doesn't include the emissions associated with burning that fuel. Finally, a well-to-wheel life cycle analysis accounts for all associated emissions, including

[44] Carbon intensity can be measured in kilograms of carbon dioxide equivalent per barrel of crude oil (kg CO_2e /barrel), or in grams of CO_2e per megajoule (g/MJ). One barrel of oil has, on average, the energy equivalent of 6,193 megajoules. The carbon intensity includes non-CO_2 greenhouse gas emissions, like methane, which are converted into CO_2 equivalent using a global warming potential established by the International Panel on Climate Change.

fuel combustion in a vehicle's engine, and represents the most common and the best way to compare the emissions intensity of various crudes on an apple-to-apple basis.

As a rule of thumb, about 20–30% of emissions occur during the well-to-tank portion, with the remaining 70–80% of GHGs emitted from the combustion of fuels in vehicle engines.

3.2. Oilsands emissions intensity

Oilsands products are more carbon-intensive than most other sources of oil, because of the greater energy requirements to extract and process bitumen. From powering heavy equipment for open-pit mining to generating huge amounts of steam for in situ operations to additional processing at the upgrading or refinery stage, the general result is more GHGs emitted than for most conventional crudes. Note that while other unconventional crudes (e.g. tight oil) are often associated with significant levels of methane emissions (e.g. vented, fugitives), that is not the case with the oilsands, whose emissions primarily come from fuel combustion.

Emissions intensity ranges

Variations in techniques employed to extract and process bitumen, combined with differing resource quality and characteristics, lead to a wide range of emissions intensities that are specific to each situation. There is a threefold range between the best and the worst performer, which is crucial context that is often missed when looking at the oilsands sector's average emissions intensity (Figure 9).

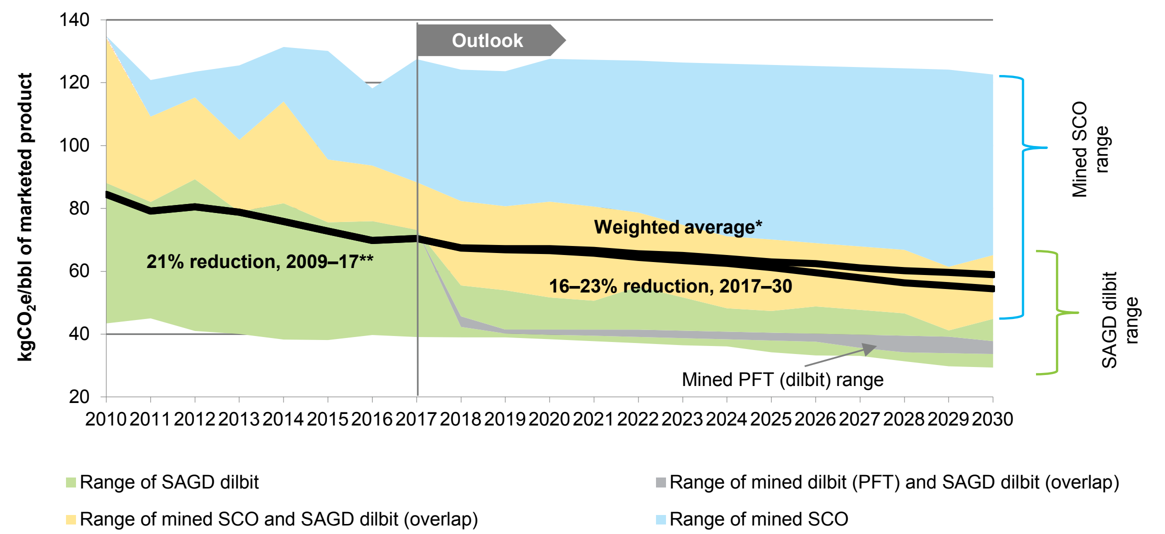
Historical trend

A 2018 study conducted by IHS Markit shows emissions intensity of the average barrel of oilsands has dropped by 21% between 2009 and 2017.[45] A caveat, which is indeed the starting point of the IHS Markit study,[46] is that this "average barrel" comprises products with significantly different qualities — that is, a theoretical blend of diluted bitumen and synthetic crude oil — whose proportions vary over time. As a result, this decreasing average reflects both actual improvements in emissions intensity and the ramp-up of less carbon-intensive operations into the mix.

[45] IHS Markit, *Greenhouse gas intensity of oil sands production* (2018), 4. Available at https://ihsmarkit.com/forms/contactinformation.html

[46] The variability in emissions intensity and how unrepresentative the average can be is a central finding of this IHS Markit report, which investigates the past and upcoming emissions intensities of various oilsands technologies.

Average and full range of oil sands GHG emission intensity by year, 2010–30 ($kgCO_2e$/bbl of marketed product)



*Estimate of total oil sands average includes oil sands CSS dilbit, SAGD dilbit, mined SCO, mined dilbit, primary, experimental, and EOR. Historical estimates for CSS were included with no intensity improvement after 2017. Estimates for primary were taken from a prior IHS Markit report (cited at the end of this note) with the same values being applied to experimental and EOR. Primary, experimental, and EOR accounted for about 7% of oil sands production in 2017 (18% including CSS), declining to 5% by 2030 (11% including CSS). Ranges shown for mined dilbit (PFT), SAGD dilbit, and mined SCO range from lower-bound minimum to upper-bound maximum. Note that prior to 2018, there was only one operating mined dilbit (PFT) facility and thus no range. Source of prior estimates IHS Markit Strategic Report *IHS Oil Sands Dialogue: Comparing GHG Intensity of the Oil Sands and the Average US Crude Oil*, www.ihsmarkit.com/oilsandsdialogue.
**Note that 2009 is not shown in this figure but is in Appendix A.

Source: IHS Markit

Figure 9. Range of upstream GHG intensity of oilsands marketed product

Source: Replicated with permission from IHS Markit[47]

Note: Oilsands products from mining and in situ operations have upstream carbon intensities that respectively varied by a factor of 1.5 to 2 in 2017 — a threefold range when considering the sector as a whole. This wide range is mainly due to the technologies employed, resource quality and operational details. Mined dilbit, produced through paraffinic froth treatment technology, has a significantly lower emissions intensity than SCO, although the difference in quality should also be noted as mined dilbit generates more emissions at the refining stage.

The oilsands industry did make some significant improvements in emissions intensity between 1990 and the early 2000s, by moving to cogeneration, less carbon-intensive fuels, and generally improving and refining the new steam-assisted gravity drainage (SAGD) production technique.

Improvements in carbon intensity have also continued over the past decade. When looking at the upstream emissions intensity, that of diluted bitumen produced through SAGD has decreased by 4% between 2009 and 2017.[48] Larger gains were made in

[47] *Greenhouse gas intensity of oil sands production*, page 32.

[48] The systems boundaries used by the IHS Markit study only include emissions associated with oilsands production, and exclude those from transporting oilsands products to the refinery. Also, those findings are greatly influenced by the boundary conditions, that is, the emissions included in the analysis. In addition to direct emissions, the IHS Markit study includes those from upstream production of fuel (e.g. natural gas, diluent) as well as the import and export of electricity that can be associated with cogeneration. Using different boundary conditions (for example only looking at direct emissions) can lead to differing results.

upgrading and mining, through better integration and increased waste heat recovery, allowing for a 21% decrease in per-barrel emissions for SCO over the same period. In mining, the introduction of a new processing technology — paraffinic froth treatment (PFT) — has paved the way for shipping diluted mined bitumen without the need for emissions intensive upgrading.[49] Today, diluted bitumen produced at the best-in-class oilsands facilities — in particular the Suncor Fort Hills mine using PFT and Cenovus Christina Lake using SAGD — has emissions intensities on par with that of the average barrel of crude oil refined in North America in 2012.[50,51,52]

Looking forward

In 2018, an IHS Markit report projected the upstream emissions intensity trends through 2030 for a variety of marketable oilsands products. The outlook does not claim to model any policy pathway, but rather uses a bottom-up approach "to capture the impact of a reasonable pace of deployment of commercial and near-commercial technologies and potential efficiency improvements on the GHG intensity of production."[53] This technology deployment happens in response to increasingly stronger investor pressure, as well as climate policies such as those that were in place at the time of that report's release — including an intensity-based carbon pricing system that created a level playing field for industrial emitters, a 100 Mt cap on oilsands emissions, and a national carbon tax. Under those conditions, the IHS Markit outlook predicts the average emissions intensity of the sector would drop by 16 to 23% range by 2030 below 2017 levels (Figure 9).

Within the mining industry, the report notes that fuel switching, cogeneration expansion and changes in fleet operations should allow for a reduction in emissions intensity of 6–10% for synthetic crude oil by 2030, with a 15–24% decrease for mined dilbit over the same period. When factoring in the ramp-up of mined dilbit, the weighted average emissions intensity of mining could decrease by 15–20% between 2017 and 2030 (Figure 10).

[49] *Greenhouse gas intensity of oil sands production.*

[50] Suncor, *Climate risk and resilience report*, 2019, 10. https://sustainability-prd-cdn.suncor.com/-/media/project/ros/shared/documents/climate-reports/2019-climate-risk-and-resilience-report-en.pdf

[51] Cenovus, *2019 Investor Day*, 2019, 44. https://www.cenovus.com/invest/docs/2019/2019%20Investor%20Day%20Presentation.pdf

[52] This is true for Cenovus on a well-to-refinery-gate basis, and for Suncor on a well-to-wheel basis. Section 4.3 elaborates the Pembina Institute's view regarding the 2012 baseline.

[53] *Greenhouse gas intensity of oil sands production*, page 19.

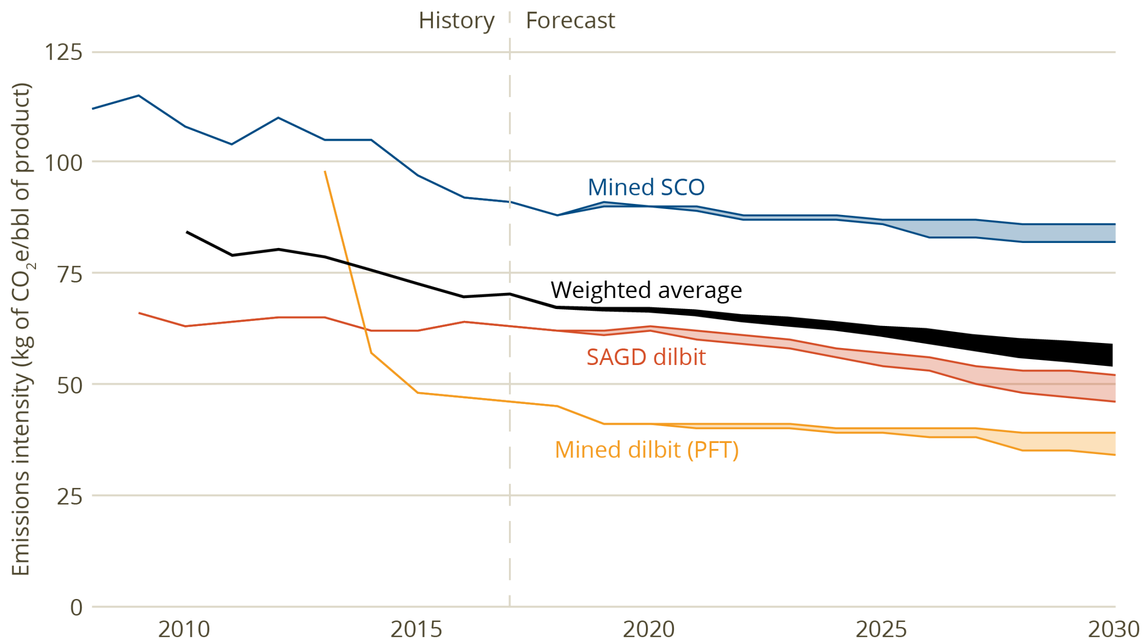


Figure 10. Historical and forecast upstream GHG intensity of oilsands marketed products

Data source: IHS Markit[54]

Note: The IHS Markit report does not forecast the emissions intensity of oilsands produced through Cyclic Steam Stimulation (CSS).

SAGD dilbit production could experience a decrease in emissions intensity in the 17 to 27% range by 2030, mainly driven by incremental gains from steam displacement technologies (e.g. solvent-based techniques), energy efficiency gains and co-generation expansion.

However, the "expanding and increasingly stringent climate policy,"[55] which was a noteworthy driver of the technology deployment modelled in the IHS Markit's outlook, is being increasingly rolled back by the Government of Alberta. The Technology, Innovation and Emissions Reduction (TIER) fund established in December 2019, for example, is a step backward in climate policy. While TIER maintains the marginal price on carbon, it replaces an industry-wide benchmark with a facility-based benchmark in the oilsands sector, thereby removing conditions for a level playing field that might create a race to the top, and thus disincentivizing the adoption of lower-carbon technologies.

Under these less stringent policy conditions, market signals, investor pressure and voluntary action could become the main drivers for industry to deploy technological innovations that realize the projected improvements in carbon intensity. In the absence

[54] IHS Markit, *Greenhouse gas intensity of oil sands production*, "Appendix A: Data tables/results," Table A-1 (2018).

[55] *Ibid*. page 4.

of a level playing field created by strong policy, there is a risk that oilsands players will respond differently to these pressures. This has a variety of possible outcomes: oilsands assets that may not be developed at all (stranded assets); incremental improvements that may buy oilsands assets more time; or breakthrough improvements that may realize the ambition of producing carbon-neutral or carbon-negative oil.

One way or the other, oilsands will only be competitive if the industry can rapidly deploy breakthrough innovation and move to the low end (in terms of carbon intensity) of the global oil supply curve — or develop non-combustion uses for the resource.

3.3. How do the oilsands compare?

For the past 15 years, a number of studies[56] have tried to quantify the life cycle carbon intensity of crudes derived from the oilsands.[57] While the majority of the literature concludes that oilsands products are relatively more carbon-intensive than most other conventional and unconventional crudes, these analyses are hard to compare one to the other for several reasons:

- **Different baselines** — Analyses may compare crude oil emissions intensity to the average barrel refined in the U.S., to a selection of crude oils or to the global average.[58]
- **Different life cycle boundaries** — Analyses measure emissions across different portions of the emissions life cycle and may treat indirect emissions differently.[59]
- **Different units of measurement** — Various units may be used to quantify emissions intensity: emissions per barrel of crude oil, per unit of energy contained in the crude oil, or per barrel of refined petroleum product.
- **Different scopes** — Analyses may estimate the carbon intensity of oil according to regions, a given technology, a marketable product, or a specific project operated by a given company.
- **Different timeframes** — Technologies have evolved quickly over the past 15 years, meaning it can be difficult to compare year to year.

[56] See Appendix D.

[57] The carbon emissions intensity of the oilsands has been a highly scrutinized issue over the past decade, in part due to the European Union's *Fuel Quality Directive* plan to single out the oilsands for being more carbon-intensive than conventional oil, before opting for a different approach in 2014. The conversation was fed with the release of a number of reports aimed at quantifying the life cycle emissions of oilsands products and comparing this to other global or North American crudes.

[58] Comparing oilsands products against a global average requires an assessment of all crudes produced, a thorough step that only one study has taken so far.

[59] Emissions from land-use change, construction and decommissioning of facilities, production of natural gas and diluents are not consistently included or approached the same way in all studies.

The studies reviewed and discussed in this section reflect this variability in inputs, assumptions and methodology, making them less comparable on an apple-to-apple basis.

IHS Markit (2014)

Finding: Life cycle GHG emissions of oilsands products are between 1% and 19% higher than the average crude oil refined in the U.S. in 2012.

To date, the most complete analysis on the life cycle emissions of various oilsands crudes and comparison between a number of continental and global crudes is a 2014 study conducted by IHS Markit, which compares the emissions intensities of oilsands products to those of the average barrel refined in the U.S.[60,61] The report finds that oilsands products have well-to-wheel GHG emissions between 1% and 19% higher than the average crude oil refined in the U.S. The study uses 2012 data and therefore does not capture the most recent improvements in extraction technologies, nor the shift of oil production to unconventional resources (e.g. shale and tight oil) in North America.

While such a thorough effort has not been repeated, a number of reports in recent years have confirmed the oilsands' relatively higher carbon-intensity when compared to other mass-produced crudes, whether on a partial or full life cycle basis.

Stanford study (2018)

Finding: Canada's oil is the fourth most carbon-intensive to produce in the world, producing on average 70% more emissions per barrel than the global average.

A 2018 peer-reviewed study by Stanford University — often referred to as the Masnadi study — using 2015 data, looked at 98% of global crude supply and found that Canada produces the fourth most carbon-intensive oil on earth, after Algeria, Venezuela and Cameroon. From the point of extraction to the refinery gate (well-to-refinery-gate), Canada's oil production emits, on average, 70% more GHGs than the average crude produced globally (Figure 11). One reason for this is the prevalence of oilsands in domestic production, which account for 64% of all Canadian oil supply

[60] IHS Markit, *Comparing GHG Intensity of the Oil Sands and the Average US Crude Oil* (2014). Available at https://ihsmarkit.com/forms/contactinformation.html

[61] The 2018 IHS Markit report contains an updated well-to-wheels life cycle analysis for each technology pathway (e.g. SAGD dilbit, mined SCO, mined dilbit) but did not release data for specific oilsands crudes.

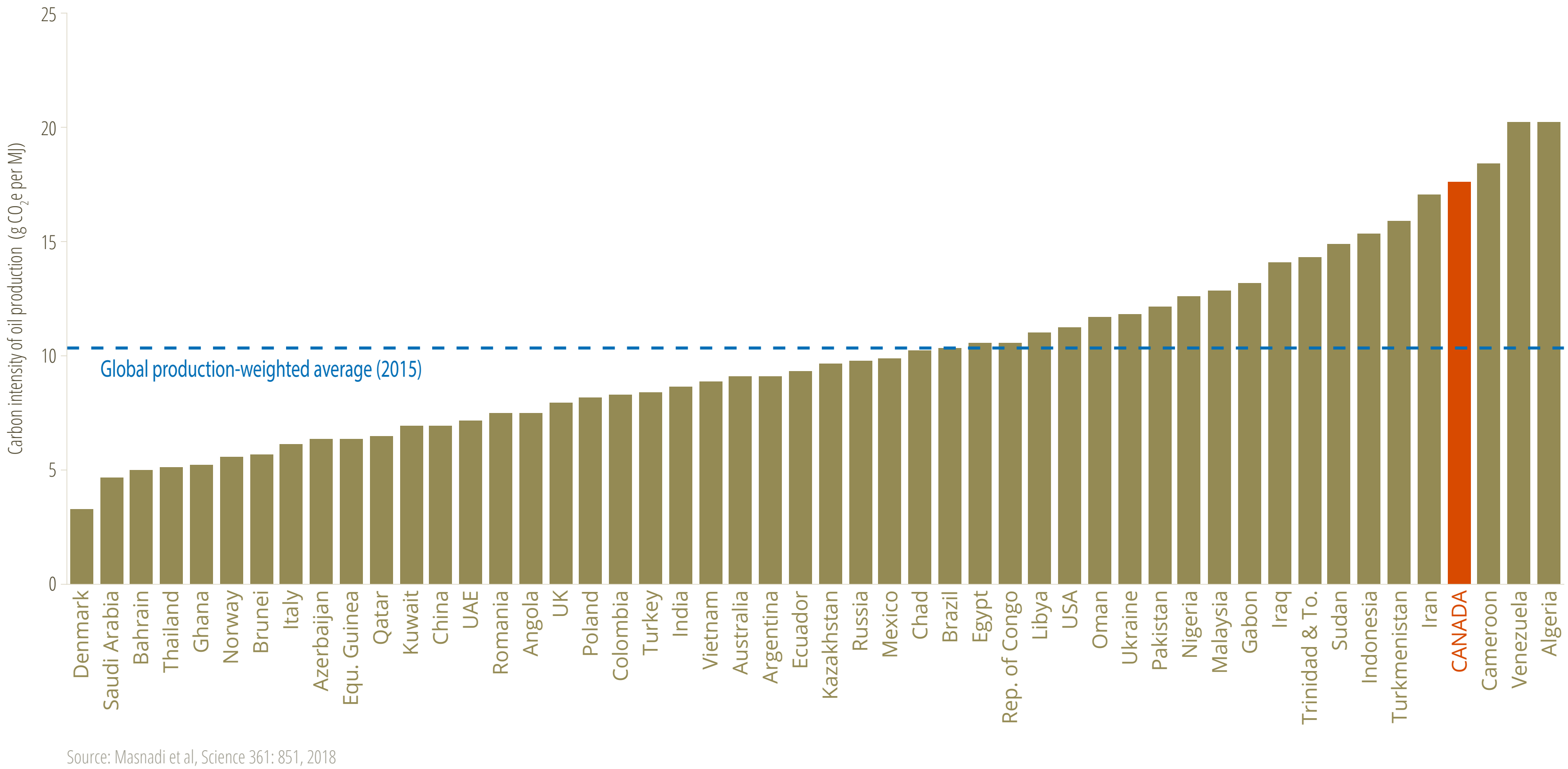


Figure 11. Well-to-refinery carbon intensity of oil production by country

Data source: Masnadi *et al*[62]

Note: Some countries produce oil with a great variability in terms of carbon intensity. While this variability was indicated with error bars in the original chart, it is not represented here to keep the chart easily readable. OPGEE, the model used in the study, includes activities that are generally excluded in industry life cycle analyses such as indirect emissions from lifetime land use and lifetime tailing ponds emissions.

[62] Masnadi *et al*, "Global carbon intensity of crude oil production," *Science* 361, Issue 6405 (2018). http://science.sciencemag.org/content/361/6405/851

Upcoming study

One limitation of the Stanford study is that the modelling uses simplified assumptions, which do not necessarily represent the real operating conditions (e.g. emissions intensity of natural gas production). A new research project funded by Alberta Innovates and Emissions Reduction Alberta, conducted by the University of Calgary, the University of Toronto and Stanford University, is investigating how using regional-specific inputs affect Canada's oil emissions intensity.

While the final results were not publicly available at the time this report was published, preliminary results indicate the use of generic inputs in the Stanford study could result in showing Canada's oil emissions intensity as higher than in reality. However, this is likely equally true for a number of other countries, whose oil carbon intensity might also change when using region-specific inputs.[63] As the best estimate available today, the Stanford study is still the leading authority on the topic.

Oil Climate Index (2016)

Finding: Oilsands are among the most carbon-intensive mass-produced global crudes on a full life cycle basis.

In 2015, the Carnegie Endowment for International Peace, in collaboration with academics from Stanford University and the University of Calgary, released the Oil Climate Index (OCI), which estimates the total carbon emissions of a number of crude oils on a well-to-wheel basis. In its 2016 update, the 75 crude oils included in the OCI represented 25% of the global oil supply.[64] The OCI includes four crudes representing about a quarter of Canada’s oilsands production, all ranked among the most carbon-intensive sources of oil presented in the tool (Figure 12).

[63] In addition, the upcoming report suggests that if region-specific data was used as input for each country, the global average will likely come down, as the default in the Stanford study for natural gas was at the high end of the range of natural gas carbon intensity.

[64] Results from the original OCI generated a number of critiques from the oilsands industry; some of these were addressed in the 2016 update of the tool.

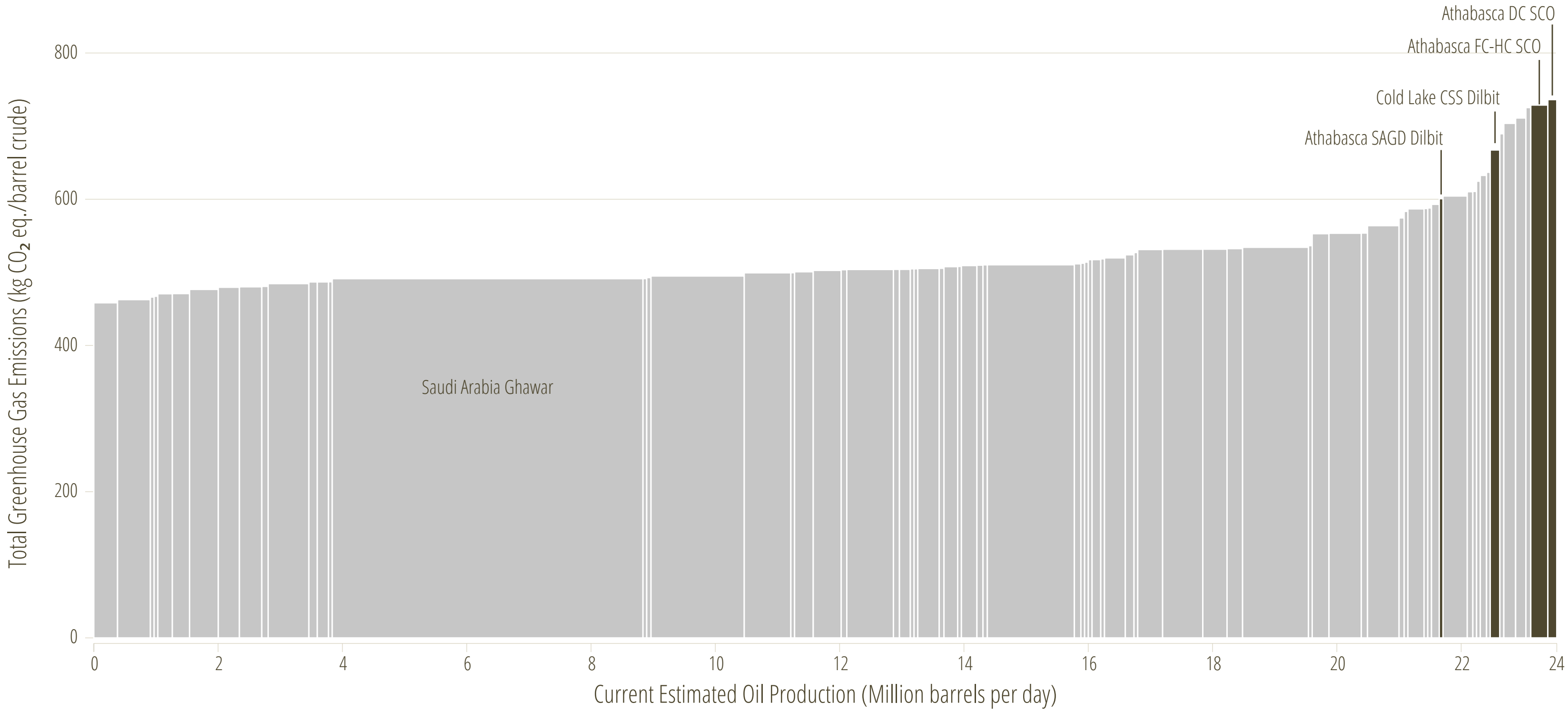


Figure 12. Life cycle GHG emissions of various crude oils included in the OCI (oilsands crudes as indicated)

Data source: Carnegie Endowment for International Peace[65]

Note: The OCI methodology assumes each crude is refined without any blending with other crudes, which is not a current practice in refineries. Methodology notes from the OCI indicate that the main criteria for including or excluding a given crude in the tool is data availability.[66]

[65] Carnegie Endowment for International Peace, Oil-Climate Index, "Viewing total emissions," 2016. http://oci.carnegieendowment.org/#total-emissions

[66] Carnegie Endowment for International Peace, Oil-Climate Index, "Methodology." https://oci.carnegieendowment.org/#methodology

Focusing only on North American crudes, the OCI suggests from well to wheel, oilsands crudes included in the benchmark are associated with 10–35% more carbon emissions than the average North American crude included (Figure 13).

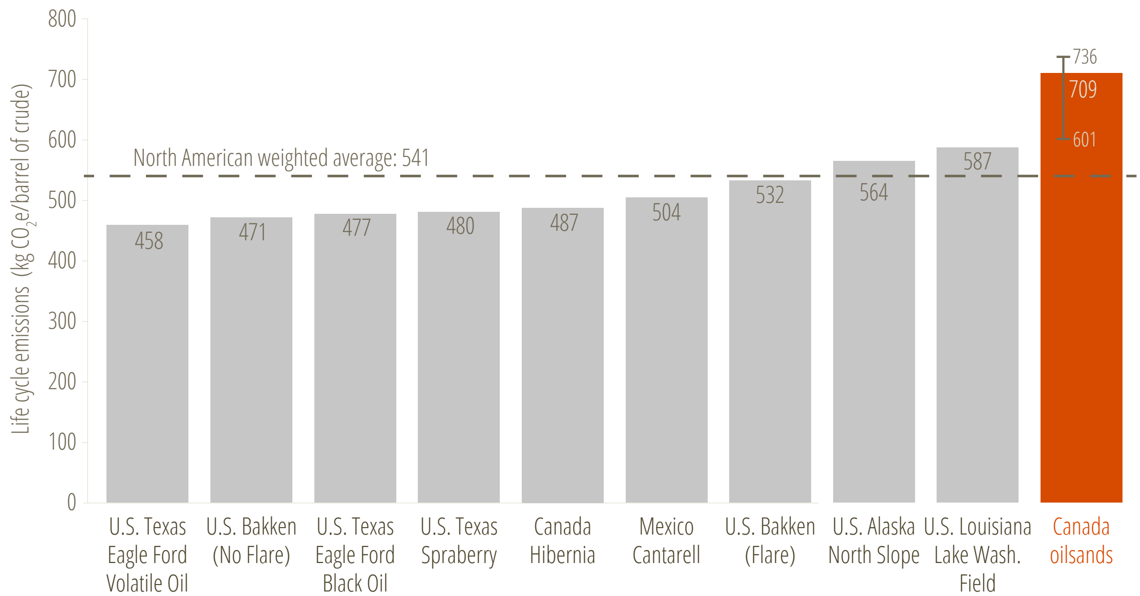


Figure 13. Well-to-wheels life cycle GHG emissions of selected oilsands crudes and a few representative North American crudes included in the OCI

Data source: Carnegie Endowment for International Peace[67]

Note: Only North American crudes from the OCI with a production over 100,000 barrels per day are represented in this figure. This chart shows the production-weighted value for oilsands' life cycle emissions, with the error bars showing the range of emissions for individual oilsands products. Oilsands crudes included in the OCI represent about 24% of oilsands production and include Cold Lake CSS Dilbit, Christina Lake SAGD dilbit, Suncor Synthetic A, Syncrude Sweet Premium.

California Air Resources Board (2018)

Finding: In terms of emissions intensity, of all crudes refined in California, oilsands products sit predominantly in the upper tier.

California's Low Carbon Fuel Standard is a regulation aimed at reducing the carbon intensity of transportation fuel used in California by at least 10% by 2020 from a 2010 baseline. The California Air Resources Board (CARB) officially adopted the Oil

[67] *Ibid.*

Production Greenhouse Gas Emission Estimator (OPGEE) model to help refineries estimate the carbon intensity of crudes they use as feedstock.[68]

According to CARB, in 2018, California imported and refined 14 crudes originating from Canada, including eight oilsands crudes. The data shows oilsands crudes to be in the upper tier end in terms of well-to-refinery-gate emissions intensity, all emitting more carbon per barrel than the average crude refined in California, with the exception of dilbit produced at Suncor Fort Hills (Figure 14).

Oilsands products included in this study can be grouped into three types with different ranges of upstream emissions intensity:

- Mined diluted bitumen (e.g. Fort Hills, Kearl Lake) has an emissions intensity on par with that of the average crude refined in California, with Fort Hills being the only one below.
- In situ diluted bitumen is usually more carbon-intensive than mined equivalent due to the greater amount of natural gas required by the technology, though a few projects can come close (e.g. Christina Dilbit Blend).
- Products made of or derived from synthetic crude oil (e.g. synbit) can be extremely carbon-intensive, with some having two to three times the carbon intensity of the average crude refined in California.[69]

[68] California Air Resources Board, "LCFS Crude Oil Lifecycle Assessment." https://ww3.arb.ca.gov/fuels/lcfs/crude-oil/crude-oil.htm

[69] Products made or derived from SCO are typically associated with fewer emissions at the refining stage than diluted bitumen.

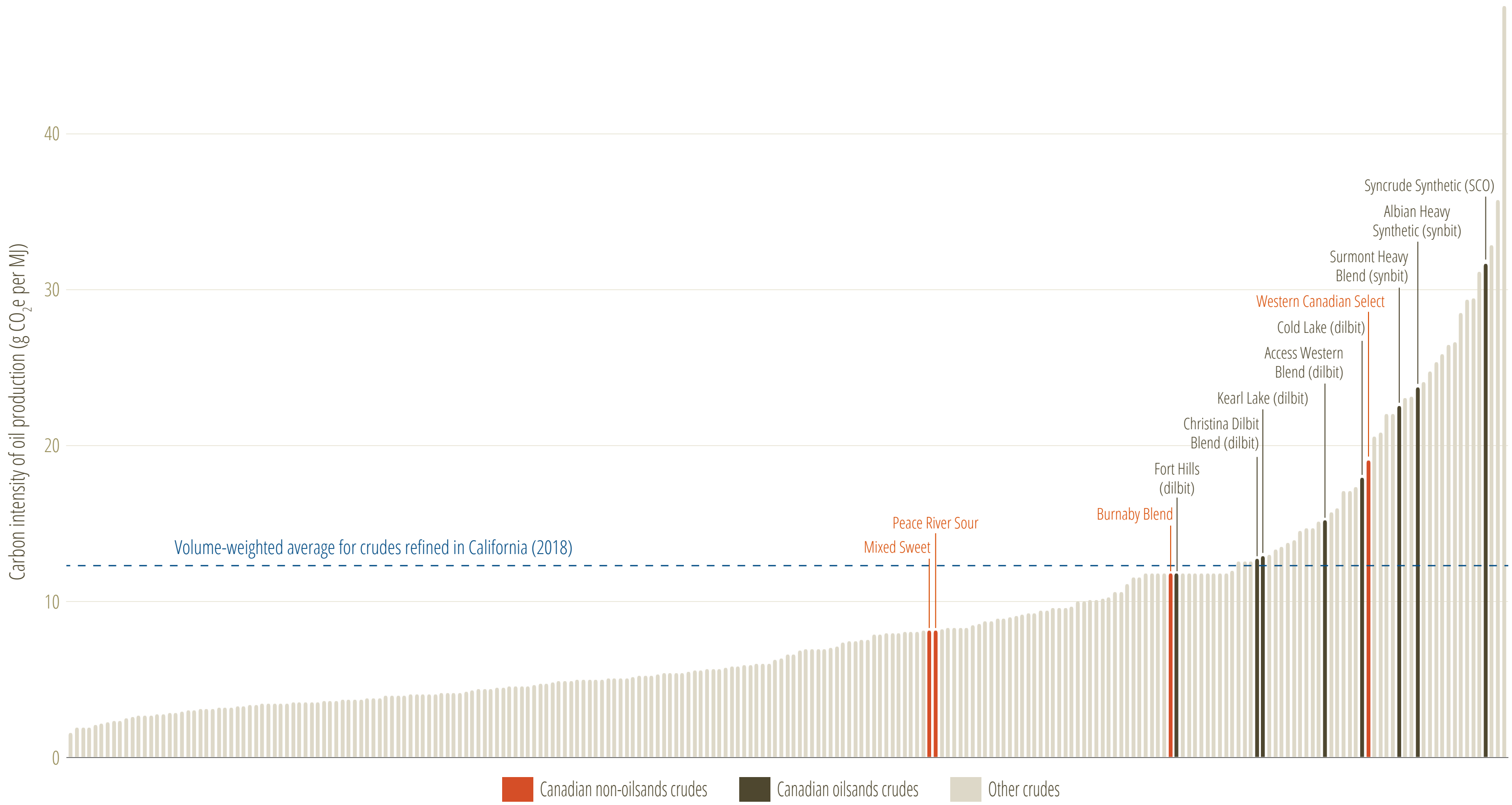


Figure 14. Carbon intensity of crudes refined in California in 2018

Data source: California Air Resources Board[70]

[70] "LCFS Crude Oil Lifecycle Assessment."

3.4. Emissions intensity summary

Most importantly to note, the oilsands sector is not homogeneous and as such "an average oilsands barrel" exists in theory only. Marketable products derived from the oilsands have significant differences in quality, from diluted bitumen with high impurities (e.g. sulphur) to light synthetic crude oil, which require different extraction techniques and need different amounts of processing. As a result, the range between highest and lowest upstream emissions intensity per barrel is nearly threefold.

While this presents a challenge in comparing oilsands products to other crude oils, this theoretical concept can still be useful in evaluating carbon performance. Differences aside, the data and literature reviewed for this report show both an increase in overall emissions from the oilsands and unambiguous improvements in the carbon intensity performance of the oilsands over the long term. One dramatic decline in per-barrel emissions occurred between 1990 and the early 2000s, mostly driven by a shift away from carbon-intensive petroleum coke as a fuel for extraction processes, as well as energy efficiency gains and reliability improvements. Continuous improvements have further reduced the carbon intensity of each marketable oilsands product between 2009 and 2017, by 21% for mined synthetic crude oil, and a more incremental 4% for diluted bitumen produced through SAGD.[71] The decline in sector emissions intensity for the sector as a whole reflects both the technological improvements deployed in the sector and the ramp-up of less GHG-intensive operations in the mix.

Lastly, because oilsands bitumen is extra-heavy oil with high levels of impurities, its extraction and processing are consistently associated with higher emissions than lighter and more conventional crudes. On all benchmarks available, and despite variations in crude oils included in the analysis, oilsands crudes are consistently classified in the upper tier of the most carbon-intensive crudes. When compared against other sources of *heavy* oil, however, a number of oilsands crudes show significantly better carbon performance.

This section would not be complete without pointing to the need for better data on the carbon performance of the sector, both in absolute and relative terms. Canada's climate targets, including the new 2050 net-zero objective, demand deep decarbonization of the sector, which can only be met with improved, transparent and consistent assessment of the carbon performance of oilsands players. It is also consistent with the demands of investors and civil society at large, asking for an improved understanding of the oilsands' carbon challenge in the face of a rapid decarbonization of Canada's economy.

[71] IHS Markit, *Greenhouse gas intensity of oil sands production*, "Appendix A: Data tables/results," Table A-1 (2018).

4. Looking forward: Is the power of technology enough?

For the past 50 years, the oilsands has been a story of technological innovation. Research and development efforts led by industry alliances and arm's-length government organizations have allowed the sector to build and expand. In 2020, a number of organizations continue to advance the environmental performance of the oilsands.[72] As carbon competitiveness is paramount to the long-term viability of the industry in a decarbonizing world, curtailing emissions has been identified as one of the primary challenges to tackle. But decreases in oilsands emissions are increasingly hard to come by, because many of the easiest reductions have already been achieved.

Broadly, the industry has focused its efforts on four technology levers:

- Improve energy efficiency of operations (e.g. better integration of mining and upgrading operations, development of cogeneration)
- Switch to relatively lower-carbon fuels (e.g. substituting petroleum coke with natural gas)
- Deploy carbon capture, utilization and storage (CCUS)
- Develop and deploy new oilsands extraction technologies.

Energy efficiency and fuel-switching have historically delivered the bulk of emissions reductions but hold limited additional potential in upcoming years.[73] While those measures have delivered noticeable reductions in emissions intensities for a number of oilsands projects, these improvements have been largely offset by the growth in oilsands production, leading to an increase in oilsands' overall emissions.

More recently, the deployment of CCUS has cut the emissions of a couple of oil and gas projects significantly.[74] It is important to highlight such costly projects were only made

[72] These organizations include Alberta Innovates (AI), Emissions Reductions Alberta (ERA), Canada's Oil Sands Innovation Alliance (COSIA), and the Clean Resource Innovation Network (CRIN).

[73] Specific to fuel switching, there will be only one facility left running on petroleum coke (Syncrude Mildred Lake) once the Suncor base mine replaces its petroleum coke boilers by 2023.

[74] Of the two CCUS projects deployed in Alberta, only the Quest project operates in the oilsands. Originally launched by Shell in 2015, Quest now belongs to Canadian Natural Resources Limited. The project is designed to annually capture 1.2 Mt CO_2e from the Scotford upgrader in Edmonton and permanently sequester these emissions underground.

possible through public subsidies[75] in the absence of strong policy and market incentives to build the business case for CCUS (e.g. carbon pricing or tax credit per tonne of CO_2e captured and reused at a level approaching $80). For these reasons, unless governments decide to massively invest in this technology — or there is a significant increase in a price on carbon — CCUS is not likely to play a significant role in cutting the sector's emissions.

Governments and industry continue to develop novel extraction technologies that have the potential to drastically reduce emissions. One of the most promising technologies is the use of solvents instead of, or in combination with, steam for in situ production, where most of the oilsands sector growth is expected through 2040.[76] There are a variety of solvent technologies with the potential to reduce the carbon intensity of new facilities up to 80%, while reducing capital and operating costs.[77]

Although technological developments and solutions sound promising on paper, there remain challenges to overcome:

- Commercial and near-commercial technologies that can be used to retrofit existing projects (e.g. solvent or non-condensable gas co-injection) only reduce the emissions intensity of oilsands projects by 10–30%.[78] Even if such technologies are widely deployed, they are unlikely to reverse the curve of absolute emissions from the sector, since emissions intensity gains will continue to be offset by the growth in oilsands production.
- Promising technologies that could cost-effectively cut per-barrel emissions by more than half cannot be used to retrofit existing operations — they only apply to new projects, which are expected to represent a marginal portion of the production growth.[79]
- The applicability and the performance of many of these technologies are highly dependent on the characteristics of a specific oil reservoir, which vary greatly.

[75] The Alberta government and the federal government respectively contributed $745 million and $120 million (a combined 64%) to Quest's overall cost of $1.35 billion. Shell estimated the cost of capturing and sequestering one tonne of CO_2 at the Quest project at $80/tonne. (Deborah Jaremko, "Quest CCS project reaches big CO_2 storage milestone," *JWN,* May 24, 2019. https://www.jwnenergy.com/article/2019/5/quest-ccs-project-reaches-big-co2-storage-milestone-costs-trending-down/)

[76] Canada Energy Regulator, *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040* (2018). http://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html

[77] Canadian Energy Research Institute, *Economic Potentials and Efficiencies of Oil Sands Operations: Processes and Technologies*, Study No. 164 (2017), xii. https://ceri.ca/assets/files/Study_164_Full_Report.pdf

[78] Oil Sands Advisory Group, *Recommendations on Innovation in the Oil Sands Sector* (2017). Available at https://open.alberta.ca/dataset/e5a69f3a-c39a-4d3d-9ae2-b88a9bbecea4/resource/2f9d384d-bf64-4132-bd25-4bcaf6b19ecb/download/osag-recommendations-on-innovation-in-the-oil-sands-sector.pdf

[79] Canada Energy Regulator, *Canada's Energy Futures 2019 Supplement: Oil Sands Production.* https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2019lsnds/index-eng.html

If deployed on a wide scale, promising retrofit solutions and new extraction technologies could undeniably improve the carbon competitiveness of a number of oilsands projects. However, deployment of *breakthrough* technology (e.g. CCUS) is required to substantially bend the oilsands emissions trajectory and align with Canada's Paris commitments.

When combining the most optimistic scenarios, in terms of emissions intensity improvement, with government oilsands production projections, the absolute emissions of the oilsands could plateau sometime during the 2040s, at best. Oilsands emissions represent a growing share of a shrinking carbon pie, on a collision course with Canada's trajectory toward becoming carbon-neutral in 2050. (See Figure 15).

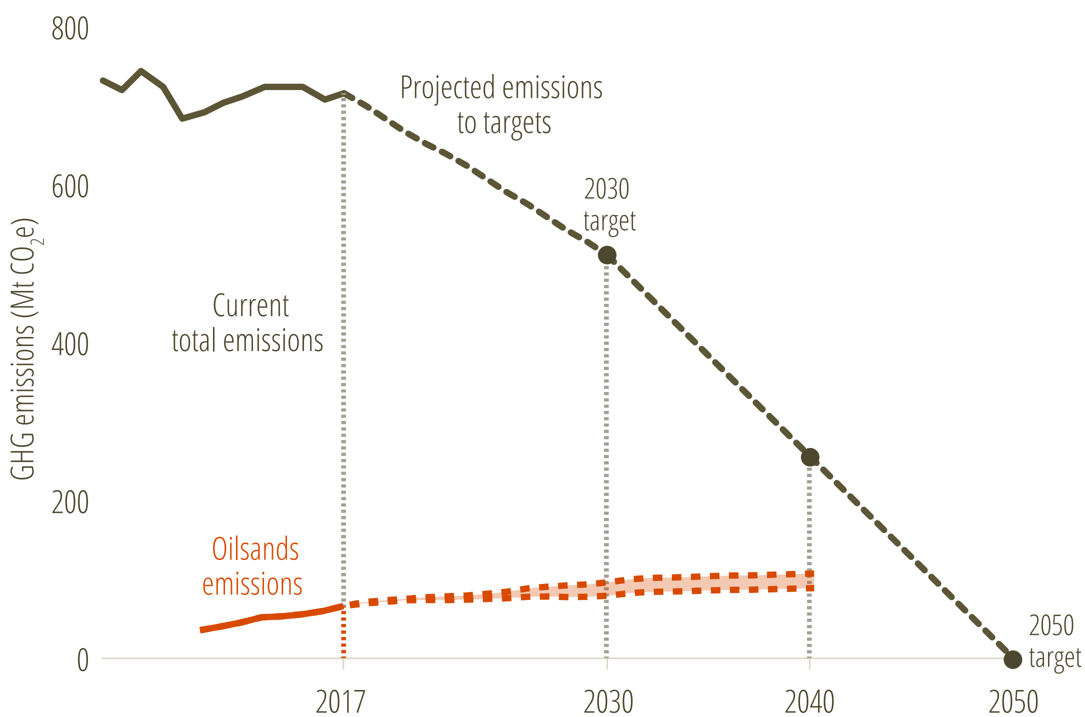


Figure 15. Share of the oilsands emissions in Canada's carbon commitments under a range of improvement scenarios

Data source: ECCC,[80] CER,[81] IHS Markit[82]

Note: The range of oilsands emissions between 2017 and 2040 is derived from two scenarios for intensity improvements on an oilsands product basis (SCO, SAGD dilbit, CSS dilbit, mined dilbit, primary production): the top line represents oilsands' emissions intensity frozen at 2017 levels; the bottom line represents the lower-bound case from the 2018 IHS Markit report. In this analysis, emissions intensities are assumed to remain at 2030 levels between 2030 and 2040 — as the IHS Markit report only predicts emissions intensities until 2030. Emissions represented in this figure use different boundary conditions than those proposed under the Oil Sands Emissions Limit Act.

[80] *Canada's GHG and Air Pollutant Emissions Projections 2018*.

[81] Canada Energy Regulator, *Canada's Energy Futures 2019 Supplement: Oil Sands Production*. https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2019lsnds/index-eng.html

[82] IHS Markit, *Greenhouse gas intensity of oil sands production*.

As noted in Section 3, in the absence of strong policy mechanism, market signals, investor pressure and voluntary action will be the motivation for industry players to deploy technological innovations that would drive the sector on its path to carbon-neutral or carbon-negative production before 2030. While the industry should actively keep developing non-combustion uses of bitumen to find new market for Alberta's oilsands resources,[83] it is going to take the development and deployment of breakthrough technologies (as opposed to incremental improvements) for the sector to decrease its absolute carbon emissions in line with Canada's climate commitments — and to remain competitive as global energy systems change.

[83] Stantec, *Bitumen Beyond Combustion — Phase 2 Report*, prepared for Alberta Innovates (2018). https://albertainnovates.ca/wp-content/uploads/2018/04/BBC%20-%20Report%202.pdf

5. Recommendations to improve oilsands climate performance

The Pembina Institute has five recommendations to address some of the challenges outlined in this report:

1. Establish strong regulations to decarbonize the industry
2. Define and enforce sector emissions targets for 2030 and 2050, with five-year increments
3. Support an innovation ecosystem to deliver breakthrough technologies
4. Improve emissions monitoring and analysis
5. Appoint credible and effective energy regulators

These recommendations may help ensure the oilsands sector decreases its absolute emissions in line with Canada's climate commitments and remains competitive and continues to contribute to the country's wealth in a decarbonizing, 21st century global economy.

1. Establish strong regulations to decarbonize the industry

Intentional effort is required to encourage a shift toward low- and zero-carbon production, by creating strong incentives for the development and deployment of breakthrough innovation. By creating a level playing field and encouraging a race to the top, smart policies can create opportunities to lower the emissions intensity of existing projects and create incentives for those projects to be best-in-class, while fostering research and development into breakthrough technologies. Recognizing the willingness of leading companies to adopt aggressive decarbonization targets, as well as mounting investor pressure to decarbonize the sector, governments need to implement policies that will drive carbon-neutral — or even carbon-negative — oilsands production.

Current situation:

- The Technology, Innovation and Emissions Reduction (TIER) fund established by the Government of Alberta in January 2020 is a step backward in climate policy, instituting a hybrid approach to the oilsands sector where most companies are subject to a facility-based benchmark. In contrast, the previous provincial regulations were meant to accelerate the adoption of lower-carbon technologies through an industry-wide benchmark that created both a level playing field and a race to the top.
- TIER maintains the same marginal price on carbon as the previous regulations ($30 per tonne of CO_2e); however, the price signal remains at a level that is not high enough to encourage facilities to pursue more ambitious retrofits, including the deployment of breakthrough technologies such as CCUS, which are needed to ensure the competitiveness of the oilsands.
- Like the previous regulations it replaces, TIER re-allocates a portion of the funds it collects to low-carbon technology development and deployment.

2. Define and enforce sector emissions targets for 2030 and 2050, with five-year increments

Meeting our 2030 and 2050 climate targets will require all sectors of our economy — and all Canadians — to do their fair share to contribute to the global effort of limiting the average temperature increase to 1.5°C. Decreasing GHG emissions reduction targets need to be set for the oil and gas sector, in five-year increments that would allow Canada to meet its 2030 national objective and its pledge to become a net-zero carbon emitter by 2050. As well, processes should be developed to demonstrate the adherence of new projects and expansions with the sectoral and national carbon budgets, as well as to limit operations when emissions risks exceed the defined carbon budget.[84,85]

Current situation:

- Oilsands are the fastest-growing source of emissions in Canada since 2005 and are projected to remain so through 2030. Oilsands emissions are predicted to represent 22% of the country's carbon budget in that year.
- Legislation for Alberta's cap on oilsands emissions, aimed at limiting carbon pollution to 100 Mt annually, was established in 2016, but has not been translated into regulation (and, therefore, cannot be enforced) as of February 2020.
- Several factors, including industry's voluntary actions, market signals and Canada's climate targets, point to the demand for increased ambition, above and beyond a 100 Mt limit.

[84] Emissions accounting should be done with a methodology similar to that of the Carbon Competitiveness Incentive Regulation (CCIR) instituted by the Government of Alberta in January 2018. It accounts for indirect emissions like those from energy currencies imported and exported from an oilsands facility (e.g. electricity, heat, and hydrogen). Indirect emissions from natural gas and diluent production, as well as from land use changes, could also be considered. *Carbon Competitiveness Incentive Regulation*, December 2017. https://www.alberta.ca/carbon-competitiveness-incentive-regulation.aspx

[85] Enforcing the sectoral carbon budget should employ an approach similar to the recommendations made by the Oil Sands Advisory Group (OSAG) to the Alberta Government for implementing the oilsands emissions limit that was established by the Alberta Climate Leadership Plan in May 2017. For more information, see *The Oil Sands Advisory Group (OSAG) recommendations on implementation of the oil sands emissions limit established by the Alberta Climate Leadership Plan (ACLP)*, May 2017. https://open.alberta.ca/publications/9781460134740

3. Support an innovation ecosystem to deliver breakthrough technologies

A robust ecosystem to support innovation, research and development needs to be funded and fostered so it can deploy solutions aimed at delivering breakthrough reductions — beyond incremental improvements — in emissions of current oilsands projects, as well as non-combustion uses of Alberta's oil and gas resources. This effort should be funded by industry and through revenue recycling from emissions reductions programs such as TIER. Besides improving the carbon competitiveness of Canada's oil and gas industry, such innovation represents an opportunity to export technologies and knowledge that the rest of the world will likely require to decarbonize their own energy systems.

Current situation:

- For the past 50 years the oilsands have been a formidable story of technological innovation to unlock the potential of the third-largest oil reserve on earth. A similar effort is required to connect Alberta's resources with the challenge of our times, reducing absolute emissions in an unprecedented way and tackling climate change in order to thrive in an increasingly decarbonizing economy.
- Two decades into the 21st century, the sector has a number of ready-to-deploy technologies that can further improve the carbon-performance of its products, yet the pathway to carbon-neutral — or carbon-negative — oil is still unclear.
- Alberta already benefits from an active ecosystem to advance its decarbonization objectives, which includes organizations like Alberta Innovates (AI), Emissions Reduction Alberta (ERA), Canada's Oil Sands Innovation Alliance (COSIA), the Clean Resource Innovation Network (CRIN), the Alberta Clean Technology Industry Alliance (ACTia) as well as research in academia (e.g. the Global Research Initiative in Sustainable Low Carbon Unconventional Resources at the University of Calgary).

4. Improve emissions monitoring and analysis

Credible data and analysis are necessary to support a fact-based discussion about the future of the oilsands sector. Existing measurement, monitoring and reporting processes for oilsands emissions must be reviewed, strengthened and standardized in order to produce coherent data and enhance the transparency of the sector. As well, further analysis looking at existing and upcoming technology pathways is required to better situate oilsands products' carbon intensity on the global supply curve.

Current situation:

- Some questions have been raised about the accuracy of GHG emissions reporting, leading to significant differences between reported emissions estimates and observed actual emissions in some cases.[86,87]
- Measurement and monitoring processes need to be improved to ensure the timely availability of granular, accurate GHG emissions data from oilsands operations, including indirect emissions.

[86] Liggio et al., "Measured Canadian oil sands CO_2 emissions are higher than estimates made using internationally recommended methods."

[87] While the findings of this report highlight the need for improved measurement, monitoring and reporting processes for oilsands emissions, the Pembina Institute continues to rely on official emissions reporting.

5. Appoint credible and effective energy regulators

Effective energy regulators are needed both provincially and federally. They must be transparent and independent, with the ability to incorporate robust environmental and climate considerations into their decision-making, while having both the mandate to enforce regulations and the capacity to follow through on that enforcement.

Current situation:

- In 2017, after broad consultation with Canadians, the Expert Panel on the Modernization of the National Energy Board found that the federal energy regulator had lost the trust of many Canadians.[88] To address the loss of trust and the perceived lack of independence, the Canada Energy Regulator was formed in 2019; this body is required to consider climate impacts for all projects it reviews.
- Approaches to assessing climate change in federal project reviews are currently being developed via the Strategic Assessment of Climate Change. To date, the proposed approaches have fallen far short of what is necessary to ensure that new projects and project expansions are consistent with our obligations under the Paris Agreement.[89]
- In 2013, the Alberta Energy Regulator (AER) was formed as an arm's-length, single regulator with the mandate to regulate issues related to the environmental impacts of energy development in the province. In its years of operation, the AER has failed to deliver crucial environmental programs intended to monitor the cumulative impacts of ongoing oil, gas, and coal development, and has further failed to meaningfully incorporate climate considerations in recent decisions and recommendations, such as the Joint Review Panel's 2019 report[90] for the Teck Frontier Oilsands Mine.[91]
- The enforcement program of the AER relies primarily on self-reporting, resorting to meaningful enforcement actions only when compliance is an issue. Transparency of enforcement continues to be a problem at the AER. For oilsands-related offences, the AER does not publicly release any compliance reporting, or report on the enforcement actions taken in instances where operators are not compliant.

[88] Expert Panel on the Modernization of the National Energy Board, *Forward, Together — Enabling Canada's Clean, Safe and Secure Energy Future: NEB Modernization Expert Panel Report: Volume II — Annexes* (2017). https://www.nrcan.gc.ca/public-consultations/closed-consultations-public-enga/neb-modernization-expert-panel-report/19667

[89] Nichole Dusyk, Isabelle Turcotte, *A strategic assessment of climate change: Pembina Institute comments on the federal draft strategic assessment of climate change* (Pembina Institute, 2019), 4. https://www.pembina.org/pub/strategic-assessment-climate-change

[90] Joint Review Panel, *Teck Resources Limited Frontier Oil Sands Mine Project* (2019). https://www.ceaa-acee.gc.ca/050/evaluations/document/131106

[91] The report did not discuss if climate impacts from the project were an adverse effect, or needed to be mitigated.

6. Conclusion

This report is intended to help depolarize the conversation about continued production of oil from the oilsands while the sector actively decarbonizes, in line with Canada's GHG reduction targets. The intention is to establish a basic, commonly agreed-upon set of facts about Alberta's oilsands, their emissions impacts and trajectories, and what Canada's commitment to achieve deep decarbonization means for the sector.

Broadly speaking, these facts include:

- Carbon emissions from the oilsands sector are the fastest-growing source of emissions in Canada.
- Oilsands products are not homogeneous and there is a wide range in performance when it comes to carbon emissions intensity.
- The oilsands industry has worked towards decreasing the emissions intensity of its products in the past decades.
- Despite these improvements in carbon intensity, *absolute* carbon emissions from the oilsands continue to increase overall.
- Studies reviewed for this report consistently find oilsands products to be more carbon intensive than lighter, more conventional oil sources.
- Global shifts toward lower intensity energy options are likely to put more carbon intense crudes — such as the bulk of oilsands products — at risk over the next decade.
- The rapid development and deployment of breakthrough technologies is needed for the sector to decrease its *absolute* carbon emissions in line with our climate commitments — and to remain competitive as global energy systems change.

Ultimately, the hope is that this report, carefully and explicitly supported by available evidence and research, opens doors to further fact-based dialogue, as we all embark on this new, tough, but necessary Canadian conversation.

Appendix A. Glossary

Information for this glossary was aggregated from a variety of government and industry sources.[92]

Absolute emissions — Overall greenhouse gas emissions, usually expressed as a mass (e.g. tons of CO_2e), emitted via a specific process (e.g. combustion in a car engine), by a particular region (e.g. Canada) or through an economic activity or industry (e.g. oil industry) over a given period of time (e.g. a year).

Bitumen — The bitumen extracted from the oilsands is a thick form of crude oil with the consistency of cold molasses, characterized by geologists as a heavy oil. Unlike light crude oil — a liquid with low density that can freely flow at room temperature — bitumen is sticky and viscous, and needs to be heated or diluted in order to flow on its own.

Carbon intensity (or emissions intensity) — This refers to the greenhouse gas emissions per unit of economic activity. A common metric in the oil industry is emissions per barrel of crude oil produced (e.g. kg CO_2e /barrel), although the emissions intensity is sometimes expressed per unit of energy contained in the oil itself (e.g. grams of CO_2e per megajoule, or g CO_2e/MJ). The emissions intensity of a given crude oil can be calculated for various scopes of emissions, that is including varying activities associated with oil production (e.g. direct emissions, well-to-tank life cycle analysis).

Carbon budget — A carbon budget refers to the amount of greenhouse gas emissions the world can collectively emit before triggering a certain degree of global warming (e.g. 1.5°C to 2°C of global warming in the case of the Paris agreement).

CO_2 equivalent (CO_2e) — This metric includes the conversion of non-CO_2 greenhouse gases, such as methane, into their CO_2 equivalent using global warming potentials established by the International Panel on Climate Change (IPPC).

Cogeneration — In oilsands operations, natural gas can be combusted in a steam turbine to generate both steam, which is used to extract the underground oilsands resource, and electricity, which is used on-site or sold back to the electrical grid. Cogeneration can reduce the emissions from an oilsands project if it replaces higher-emissions processes, such as combusting petroleum coke to create steam and releasing heat as waste.

[92] References include Government of Alberta, "Oil sands facts and statistics." https://www.alberta.ca/oil-sands-facts-and-statistics.aspx; Natural Resources Canada, "Crude oil facts: Canadian resources." https://www.nrcan.gc.ca/crude-oil-facts/20064; The Oil Sands Magazine. https://www.oilsandsmagazine.com

Conventional extraction — Conventional extraction is one of two techniques used to extract crude oil, and usually involves a single well that uses naturally-occurring underground pressure to push lighter, free-flowing crudes to the surface. *As opposed to **unconventional extraction.***

Diluted bitumen (dilbit) — Raw bitumen can be diluted with a condensate (e.g. natural gas liquid) to meet pipeline specifications so it can be shipped to market (i.e. refineries). Known as diluted bitumen, or dilbit, this mixture can only be processed in refineries equipped to work with heavy crude oils, called high conversion refineries. Because diluted bitumen is a heavier oil with higher sulphur content, transforming it into transportation fuels requires more processing than most conventional crudes, which translates into additional carbon emissions at the refining stage.

Direct emissions — Direct emissions represent all greenhouse gas emissions emitted by a facility, and include emissions from energy currencies (e.g. electricity, steam) that may be exported and used outside of the plant. In the case of the oilsands, a number of facilities have cogeneration units that produce steam and electricity, whose surplus is exported to the grid.

Downstream — The final phase of oil and gas production, in which the crude is refined into useable and sellable products such as gasoline or jet fuel, is the downstream sector. Sometimes, including in this report, downstream refers to the end use of refined petroleum products (e.g. combustion in a car's engine). *As opposed to the **upstream** sector.*

Heavy oil — Heavy oil has a high viscosity, and is difficult to move through pipelines. A crude oil's classification as "heavy" is based on its American Petroleum Institute (API) gravity. Heavy oil has an API gravity lower than 20 degrees. With an API gravity lower than 10 degrees, bitumen from the oilsands is sometimes referred to as "extra-heavy oil."

High-conversion refinery — This is a more complex refinery capable of processing heavy crude oils, including those with high sulphur content such as diluted bitumen from the oilsands.

Hydraulic fracturing — This process combines long horizontal wells and the injection of water, sand and chemicals underground at high pressure to fracture a given rock formation and release light hydrocarbons, whose liquid portion is known as tight oil or shale oil.

In situ recovery — One of two unconventional extraction techniques used to recover bitumen from the oilsands (for the other see *open pit mining*). 81% of Alberta's oilsands are too deep to be accessed from an open pit mine. In situ or "on site" extraction uses technologies — such as injecting steam to heat the bitumen in the case of SAGD — to separate the bitumen from solids while still underground, before pumping it to the surface. As a result, this method does not generate tailings ponds.

Oilsands — Oilsands are a naturally occurring mix of bitumen, sand and water, with significant levels of sulphur and other impurities (e.g. heavy metals, asphaltenes). Globally, they are largely found in Alberta and Venezuela, both with the top three largest proven reserves of oil in the world.

Open pit mining — One of two unconventional extraction techniques to recover bitumen from the oilsands (for the other see *in situ recovery*). Oilsands are shoveled directly from the mine into trucks and sent for processing, where the bitumen is separated from solids and water. Mining operations generate tailings ponds, where these residues are collected. In 2018, mining accounted for almost half of oilsands extraction, although bitumen accessible via this method comprises about 19% of oilsands reserves.

Paraffinic froth treatment (PFT) — Paraffinic froth treatment is a relatively new technique that removes impurities and precipitates from some of the heaviest components of bitumen (such as asphaltenes), thus allowing mined bitumen to meet pipeline standards when diluted.

Petroleum coke (petcoke) — Petroleum coke is a waste product left over from refining oilsands crude. In some operations it is burned to generate heat to produce steam. However, it has a higher carbon and sulfur content than coal, and therefore results in higher carbon emissions. It is gradually being replaced in many operations by cogeneration using natural gas.

Steam-Assisted Gravity Drainage (SAGD) — SAGD is an in situ bitumen extraction method that uses steam to heat the bitumen before extraction, in order to separate it from surrounding sand. The bitumen is then pumped to the surface and separated from any water.

Sweet oil — Sweet oil is a crude classified by low amounts of sulfur content, as opposed to sour crude, which is high in sulfur content.

Synthetic crude oil (SCO) — SCO results from upgrading raw bitumen into a marketable product with characteristics similar to a light, sweet crude oils (including a low sulphur content). It can be theoretically be processed by most refineries.

Tight oil (shale oil) — This is light oil trapped in geological formations associated with low porosity and low permeability, making it difficult to recover. Tight and shale oil is usually extracted by using unconventional techniques such as the combination of horizontal drilling and hydraulic fracturing.

Tailings ponds — When water is added to separate bitumen — on average less than 20% of the volume of excavated oilsands — from the remaining solids (e.g. sands, silts), both water and solids are sent to tailings ponds after the separation. Tailings ponds are only associated with oilsands mining technique (as opposed to in situ recovery techniques).

Unconventional extraction — Unconventional techniques employ inventive ways of extracting oil (both light and heavy crudes) from unconventional reservoirs. The most well-known unconventional technique is hydraulic fracturing. Techniques to extract bitumen from the oilsands are classified as unconventional (as opposed to **conventional extraction).**

Upgraded bitumen (upgrading) — By using chemical reactions at high temperatures, raw bitumen can be upgraded into a synthetic crude oil (SCO), which has characteristics similar to lighter sweet crude oils (including a low-sulphur content) and can theoretically be processed by most refineries. This pathway is generally associated with more carbon pollution for extraction and refining on a per-barrel basis than refining diluted bitumen.

Upstream — The upstream sector of oil and gas, also known as the exploration and production (E&P) sector, is the part of the industry where the crude oil and gas is discovered and subsequently extracted (*as opposed to the **downstream** sector*).

Well-to-refinery-gate — In a life cycle analysis of oil emissions, the well-to-refinery-gate segment estimates emissions from extraction and processing only, including diluting and upgrading but not refining.

Well-to-tank — In a life cycle analysis of oil emissions, the well-to-tank segment assesses emissions from the point of extraction through the value chain to the delivery of a transportation fuel to the tank of a vehicle, but doesn't include the emissions associated with burning that fuel.

Well-to-wheel — This life cycle analysis adds to the well-to-tank scope those emissions associated with fuel combustion in a vehicle's engine. This represents the best way to compare the emissions intensity of various crudes on an apple-to-apple basis.

Appendix B. Estimate of future Alberta oilsands' GHG emissions

An estimate of possible future Alberta oilsands emissions are presented for two cases:

- All projects that are currently operating, are under construction, or have been approved[93] by the Alberta Energy Regulator (AER);
- All projects that are currently operating, are under construction, or have been approved by the AER, plus those that have submitted an application to the AER.

Inputs

The emissions for each situation above are calculated using the combined design production capacity of all oilsands plants, then adjusted to account for a capacity factor (the fact plants don't run at full capacity all the time), and, finally, an emission factor (the expected amount of emissions per barrel from the dominant technology for that type of extraction) is applied.

The bitumen production capacity for each case is based on an oilsands project database maintained by the Pembina Institute[94] and primarily updated with the most recent outlook from the AER in May 2019,[95] with manual additions for projects approved after that date.

Oilsands projects do not typically run every day of the year. To account for this, a capacity factor of 85% is used to calculate the actual oilsands production from each facility using the nominal production values. The 85% capacity factor used in this analysis is slightly lower than the average for the last decade (85.8% between 2006 and 2016) and that of the past 16 years (87.8% between 2000 and 2016).[96]

Emission factors specific to the extraction technology (mining or in situ) are used to estimate emissions (Table 3). These are based on production-weighted average emission factors for each technology calculated based on 2017 regulatory compliance data from the Government of Alberta.

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[93] See Appendix C for a detailed list of approved projects.

[94] The database was originally developed using industry and governments sources, including the *Alberta Oil Sands Industry Quarterly*. https://investalberta.ca/publications/oil-and-gas-quarterly/

[95] Alberta Energy Regulator, *ST98: Alberta Energy Outlook 2019*, May 2019. https://www.aer.ca/providing-information/data-and-reports/statistical-reports/st98

[96] Oilsands capacity factors were calculated using existing production capacity sourced from Oilsands quarterly and production data sourced from Alberta Environment and Parks, Oil Sands Information Portal, "Total Oil Sands Production Graph" http://osip.alberta.ca

Table 3. Emissions intensity of oilsands technologies in 2017

Oilsands technology	GHG emissions intensity (kg CO_2e/bbl)
In situ	68.2
Surface mining	79.8

Source: Government of Alberta[97]

Results

Table 4. Projected cumulative emissions from oilsands sector per status as of December 2019

Oilsands project status	Production capacity (bbd)[98]	Cumulative totals of GHG emissions (Mt CO_2e/yr)
Operating projects	3,624,975	83
+ projects approved and/or under construction	6,479,301	147
+ applications	7,695,401	173

Note: The '+' sign indicates that the emissions included in that row also includes those from the above phase(s). We note that 83 Mt estimate for total operating projects using this methodology is lower than the official federal government figure of 94 Mt for 2020 (referenced in Table 2). The reasons include different boundary conditions, as well as potentially conservative assumptions, such as the capacity factor, used for this analysis (as discussed below). No capacity factor has been applied to the production capacity indicated in the table.

Limitation and discussion

As with any modelling work, this analysis contains some simplifications and limitations.

First, oilsands projects are assigned a broad technology type ("mining" or "in situ"), and allocated the average emission factor of the dominant technology in this category. As a result, emission factors used in this analysis do not reflect the variety of techniques being used to produce bitumen.

Steam-assisted gravity drainage (SAGD), for example, accounts for 80% of the in situ capacity operating in 2017, with cyclic steam stimulation (CSS) technologies making up another 19%, and the remaining 1% using other in situ techniques.

[97] Data from the Specified Gas Emitters Regulation obtained from the Government of Alberta.

[98] Production capacity aggregated by the Pembina Institute.

The emission factor used to predict emissions of in situ production is derived from the Specified Gas Emitter Regulation (SGER), which solely accounts for SAGD projects. CSS projects have been characterized in the literature as emitting more GHGs on a per-barrel basis than the median SAGD project.[99] Conversely, several projects use co-injection techniques, which inject a mix of steam and solvent, and have demonstrated emissions reductions on a per-barrel basis.

Further, the emission factor used for mining is derived from SGER historical data, which only considers mines equipped with an upgrader. As a result, the emission factor includes emissions for upgrading the bitumen. In our analysis it is applied to projects like Suncor Fort Hills and Imperial Oil Kearl that do not use upgraders, leading to an overestimate of mining's emissions. A sensitivity analysis showed that the impact of this overestimate is small, and certainly within the margin of error of such analysis.

In addition, the emission intensity of mining operations (excluding upgrading) has historically increased and this trend is expected to continue for older operations, as producers access deeper, lower-quality bitumen and the distance from mines to processing facilities increases. [100] This is, however, also likely to be mitigated by improvements to the truck fleet.

Emission factors used in this analysis are constant and do not evolve over time. Although the industry is deploying technologies to improve the carbon performance of oilsands projects, the overall performance of each technology is hard to predict, as it is affected by conflicting forces. While marginal gains are expected through the implementation of technology improvements (e.g. co-injection of solvent and steam in in situ, automation in mining), these deployments cannot be economically and/or technically deployed on all projects. In addition, oilsands resources from high-quality reservoirs are typically developed first, resulting in a degradation of reservoir quality over time. Lower quality reservoirs will require more energy.

Lastly, this analysis does not include a time dimension, but rather estimates the GHG emissions if all projects considered were built and commissioned over-night. That is, this analysis does not consider that some upcoming projects are expansions or new projects aimed at replacing existing projects reaching their end of life.

[99] A 2018 study indicates that CSS projects could lead to as much as 13% more GHG emissions per barrel than SAGD. Orellana et al, "Statistically Enhanced Model of In Situ Oil Sands Extraction Operations: An Evaluation of Variability in Greenhouse Gas Emissions," *Environmental Science & Technology* (2018) https://pubs.acs.org/doi/abs/10.1021/acs.est.7b04498

[100] Benjamin Israel, "The Real GHG trend: Oilsands among the most carbon intensive crudes in North America (2017)," *Pembina Institute*. http://www.pembina.org/blog/real-ghg-trend-oilsands

Appendix C. Approved Alberta oilsands projects or expansions

Table 5 lists the oilsands projects or expansions approved by the Alberta Energy Regulator as of December 2019, which are not operating and have not started construction.[101, 102] Note that some of these projects are aimed at replacing existing projects when they reach their end-of-life. The design production capacity of these projects is used in Appendix B to estimate cumulative emissions from all approved projects.

Table 5. Oilsands projects approved by the Alberta Energy Regulator as of Dec. 2019

Company	Project (or planned expansion of existing project)	Capacity (bpd)
In situ projects		***1,942,607***
Brion Energy Corporation	Dover	200,000
Cenovus Energy Inc.	Grand Rapids	180,000
Imperial Oil Limited	Aspen	150,000
MEG Energy Corp.	Christina Lake	150,000
Suncor Energy Inc.	Firebag	125,000
MEG Energy Corp.[103]	Surmont	120,000
Brion Energy Corporation	Mackay River	115,000
Husky Energy Inc.	Sunrise	105,043
Devon Canada Corporation	Pike	105,000
Cenovus Energy Inc.	Narrows Lake	85,000
BlackPearl Resources Inc.	Blackrod	80,000
Suncor Energy Inc.	Meadow Creek East	80,000
Canadian Natural Resources Limited	Kirby	60,000
ConocoPhillips Canada Limited	Surmont	57,000

[101] Alberta Energy Regulator, *ST98: Alberta Energy Outlook 2019*, May 2019. https://www.aer.ca/providing-information/data-and-reports/statistical-reports/st98

[102] Projects approved after May 2019 were manually added to the list.

[103] Alberta Energy Regulator, *Approval No. 12824*, September 9, 2019, O.C. 159/2019. http://www.qp.alberta.ca/documents/Orders/Orders_in_Council/2019/2019_159.html

Company	Project (or planned expansion of existing project)	Capacity (bpd)
Cenovus Energy Inc.	Christina Lake	50,000
OSUM Oil Sands Corp.	Taiga	45,000
CNOOC Limited	Long Lake	37,500
Cenovus Energy Inc.	Foster Creek	35,000
Connacher Oil and Gas Limited	Great Divide	24,000
Athabasca Oil Corporation	Leismer	20,000
Harvest Operations Corp.	BlackGold	20,000
Grizzly Oil Sands Ulc	May River	12,000
Surmont Energy Ltd.	Wildwood	12,000
OSUM Oil Sands Corp.	Orion	10,064
Cavalier Energy Inc.	Hoole	10,000
Husky Energy Inc.	Caribou	10,000
Sunshine Oilsands Ltd.	Thickwood	10,000
Value Creation Inc.	Terre de Grace	10,000
Devon Canada Corporation	Walleye	9,000
Grizzly Oil Sands Ulc[104]	Algar Lake	6,000
Baytex Energy Corp.	Gemini	5,000
Sunshine Oilsands Ltd.	West Ells	5,000
Mining projects		***835,510***
Athabasca Oil Sands Project (CNRL)	Jackpine	200,000
Syncrude Canada Ltd.	Mildred Lake/Aurora	200,000
Syncrude Canada Ltd.[105]	Mildred Lake Extension (MLX)	184,000
Imperial Oil Limited	Kearl	119,510
Athabasca Oil Sands Project (CNRL)	Muskeg River	115,000
Suncor Energy Inc.	Fort Hills	20,000
	Total	**2,781,117**

Source: Unless specified otherwise, source is Alberta Energy Regulator[106]

[104] Alberta Energy Regulator, *Approval No. 12665*, December 3, 2019, O.C. 280/2019. http://www.qp.alberta.ca/documents/Orders/Orders_in_Council/2019/2019_280.html

[105] Alberta Energy Regulator, *Syncrude Canada Ltd. Mildred Lake Extension Project and Mildred Lake Tailings Management Plan*, 2019 ABAER 006 (2019). https://www.aer.ca/documents/decisions/2019/2019ABAER006.pdf

[106] Alberta Energy Regulator, *ST98: Alberta Energy Outlook 2019*, May 2019. https://www.aer.ca/providing-information/data-and-reports/statistical-reports/st98

Appendix D. Past studies on oilsands life cycle GHG emissions

Over the past 15 years, a number of studies have tried to quantify the life cycle carbon emissions intensity of crude oils derived from the oilsands. The following is a selection of the most commonly referenced industry, academia and government reports investigating this issue.

Bergerson, Joule A. et al. *Life cycle greenhouse gas emissions of current oil sands technologies: Surface mining and in situ applications*, Environmental Science and Technology, 2012. https://pubs.acs.org/doi/abs/10.1021/es300718h

Brandt, Adam R. *Upstream greenhouse gas (GHG) emissions from Canadian oilsands as a feedstock for European refineries*, Department of Energy Resources Engineering, Stanford University, 2011. https://circabc.europa.eu/d/d/workspace/SpacesStore/db806977-6418-44db-a464-20267139b34d/Brandt_Oil_Sands_GHGs_Final.pdf

Charpentier, Alex D. et al. *Understanding the Canadian oil sands industry's greenhouse gas emissions,* 2009. https://iopscience.iop.org/article/10.1088/1748-9326/4/1/014005/fulltext/

Charpentier, Alex D. et al. *Life cycle greenhouse gas emissions of current oil sands technologies: GHOST model development and illustrative application*, Environmental Science and Technology, 2011. https://pubs.acs.org/doi/abs/10.1021/es103912m

Gordon, Deborah et al. *Know Your Oil: Creating a Global Oil-Climate Index*, Carnegie Endowment for International Peace, 2015. https://carnegieendowment.org/files/know_your_oil.pdf

IHS Markit. *Comparing GHG Intensity of the Oil Sands and the Average US Crude Oil*, 2014. Available at https://ihsmarkit.com/forms/contactinformation.html

IHS Markit. *Greenhouse gas intensity of oil sands production*, 2018. Available at https://ihsmarkit.com/forms/contactinformation.html

Lattanzio, Richard K. *Canadian Oil Sands: Life-Cycle Assessments of Greenhouse Gas Emissions*, Washington (DC): Congressional Research Service, 2014. https://fas.org/sgp/crs/misc/R42537.pdf

National Energy Technology Laboratory, *Development of Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels*, 2008.

Nimana, Balwinder et al. *Life cycle assessment of greenhouse gas emissions from Canada's oil sands-derived transportation fuels*, 2015. https://www.sciencedirect.com/science/article/abs/pii/S0360544215006593

TIAX LLC and MathPro Inc. *Comparison of North American and Imported Crude Oil Lifecycle GHG Emissions*, 2009. http://www.assembly.ab.ca/lao/library/egovdocs/2009/aleri/173913.pdf