Forecasting the impacts of oilsands expansion

Measuring the land disturbance, air quality, water use, greenhouse gas emissions, and tailings production associated with each barrel of bitumen production

By Jennifer Grant, Eli Angen and Simon Dyer
June 2013

In the debate over the environmental impacts of oilsands development, you’ll often hear industry proponents cite one set of statistics, and critics another. That’s because proponents often talk in the present tense — pointing, for instance, to the fact that oilsands emissions today represent a fraction of global greenhouse gas emissions — while critics point to the future, measuring today’s environmental concerns against industry’s growth projections. It’s common to hear critics state, for example, that oilsands emissions matter because their rapid growth is cancelling out the progress made in other sectors, and because this growth is the main reason Canada is unlikely to meet its global climate commitments.

While both perspectives may be accurate, when it comes to managing the impacts of oilsands development the long view is the one that counts.

Last year, the oilsands industry produced 1.9 million barrels of bitumen each day.¹ A decade from now, total bitumen production is projected to reach 3.8 million barrels per day,² and the Canadian Association of Petroleum Producers expects the industry will surpass 5 million barrels a day by the end of 2030.³ (In fact, regulators have already approved this level of production based on today’s technology — despite industry’s own forecasts⁴ showing that critical ecosystem and air quality limits are likely to be exceeded in some areas.) In total, the industry has announced or disclosed plans to produce more than 9 million barrels of bitumen per day.⁵

While it’s challenging to project how the impacts of oilsands development will change over time, there are two key elements that shape the overall footprint of oilsands development: the pace and scale of oilsands production (barrels of bitumen produced each day) and per barrel environmental impacts of oilsands production.

Many forces determine the pace and scale of oilsands production, including access to finance, key markets, oilsands resources, and critical inputs such as labour and materials. Equally important are the limits Canadian regulators establish on environmental impacts — because these limits, if designed properly, could set the ground rules for responsible oilsands development.

Why consider per-barrel impacts

The oilsands industry’s growth plans have significant implications for environmental management, but it can be challenging to understand production on such
a massive scale and given uncertain timelines. Distil the industry’s footprint down to the impacts of producing a single barrel of bitumen from the oilsands, however, and the picture becomes clearer.

The main environmental concerns related to oilsands development today include: how much water the industry consumes, how much land is disturbed and (in the case of wetlands) may never be properly restored, the volume of toxic tailings waste produced and how it is managed, and the greenhouse gas and air pollution emitted. It’s also critical to understand how the effects of each project, when measured together rather than in isolation, can have serious implications for wildlife, the integrity of nearby ecosystems, and the health of people living in the vicinity of oilsands development — now and into the future.

This fact sheet aims to quantify each of these things (land disturbance, air emissions, water use, greenhouse gas emissions, and tailings production) on a per-barrel basis, using publicly available government and industry data, as well as peer-reviewed literature. It also looks at how such impacts are likely to change in the future, as production ramps up — starting from 2010 and 2012 and projecting out to 5 million barrels a day of oilsands production in 2030.

Conducting this kind of analysis requires many assumptions about the technologies, practices, and regulations that determine the impacts of oilsands production. Our assumptions and methodology are outlined in detail in the “Methods” section at the end of this publication. Looking forward, we see significant potential to improve the environmental performance of Canada’s oilsands industry. But that improvement requires significantly strengthening policies governing oilsands development in Alberta, aggressively setting targets to reduce the per-barrel impacts of production, and moderating the pace of oilsands development where necessary to respect science-based environmental limits.

**OILSANDS EXTRACTION**

Oilsands can be mined when the oilsands deposit is close to the surface. Deeper deposits are accessed through in situ technologies that include injecting steam underground to enable extraction of the bitumen. Mining and in situ oilsands extraction have different environmental impacts and data is presented here for both extraction methods separately. Cumulative data is based on the current and projected production levels of both extraction types.

Figure 1. Oilsands expansion plans: As of October 2012, regulators have approved more than five million barrels of bitumen production per day (Data Source: Oilsands Review)
Water use intensity

Oilsands extraction consumes large amounts of water, despite current recycling efforts. In 2011, oilsands operators used approximately 170 million cubic metres (1.1 billion barrels) of water, equivalent to the residential water use of 1.7 million Canadians — or roughly the amount of water used by everyone living in Calgary and Edmonton combined. The Athabasca River is the primary source of freshwater for the industry, and oilsands mining uses three times as much fresh water as conventional oil production.\(^7\)

**Freshwater use intensity:**

In situ: 0.45 bbl/bbl  
Mining: 2.41 bbl/bbl

**Brackish water use intensity:**

In situ: 0.39 bbl/bbl  
Mining: Not applicable

**Data source:**

Oil Sands Information Portal\(^6\)  
Years: 2009-2011  
Unit: Barrels of water used per barrel of bitumen or SCO produced (bbl/bbl)

Daily freshwater use in 2022 is projected to be 4,861,389 barrels = 772,900 m\(^3\). This is equivalent to filling 4.8 million bathtubs or 309 Olympic swimming pools of freshwater every day.\(^9,10\)
Greenhouse gas emissions intensity

The oilsands extraction process consumes large amounts of energy, derived from coal-based power, natural gas, and diesel fuel. Oilsands’ greenhouse gases (GHGs) are the fastest growing source of climate change pollution in Canada. Average oilsands production is significantly more GHG-intensive than conventional oil production.\textsuperscript{11}

![Graph showing GHG emissions intensity](graph.png)

**GHG emissions intensity:**

- In situ with cogeneration: 0.083 tonnes CO\textsubscript{2}e/bbl
- In situ without cogeneration: 0.074 tonnes CO\textsubscript{2}e/bbl
- Combined: 0.082 tonnes CO\textsubscript{2}e/bbl

Mining: 0.073 tonnes CO\textsubscript{2}e/bbl
(includes GHG emissions from on-site upgrading to produce upgraded bitumen or synthetic crude oil)

Future projections for in situ GHG emissions intensity were made using the combined value. See note under “Additional Methodological Details” for further description.

**Data source:**

Government of Alberta GHG Reporting Program\textsuperscript{12}
Years: 2009-2010
Unit: tonnes of carbon dioxide equivalent emitted per barrel of bitumen or SCO produced ( tonnes CO\textsubscript{2}e/bbl )

Greenhouse gas emissions from oilsands production in 2022 are projected to be the equivalent to adding 22.6 million cars to the road in the U.S.\textsuperscript{13}
Air emissions intensity

Oilsands extraction is a major point source of air pollutants such as nitrogen dioxide and sulphur dioxide. Forecasted growth in oilsands will present challenges for meeting ambient air quality standards in north-eastern Alberta. While there have been some improvements in reducing the volumes of air pollutants produced per barrel, the overall growth in the industry means that absolute growth in air emissions will impact air quality for communities who reside in the region.

 nit
 oxides (NO\textsubscript{x}) emissions intensity:
 In situ: 61.57 g/bbl
 Mining: 81.32 g/bbl

 Sulphur dioxide (SO\textsubscript{2}) emissions intensity:
 In situ: 41.4 g/bbl
 Mining: 449.4 g/bbl

 Particulate matter (PM\textsubscript{2.5}) emissions intensity:
 In situ: 1.5 g/bbl
 Mining: 4.4 g/bbl

Data source:
National Pollution Release Inventory\textsuperscript{14}
Years: 2009-2010
Unit: grams of air pollutant emitted per barrel of bitumen or SCO produced (g/bbl)
Tailings production intensity

Tailings are a waste by-product of the oilsands mining extraction process that consist of water, clay, sand and residual bitumen, along with various salts, heavy metals and other compounds that can be toxic if concentrations are high enough. These “ponds” currently cover 176 square kilometres of the landscape, and contain 830 million cubic metres of tailings waste. There remains considerable uncertainty as to whether the tailings ponds can be reclaimed to a level that sustains functional ecosystems equivalent to those that were in existence prior to mining, and no method for regenerating displaced peatlands has been developed.\(^{15}\)

In 2010, the total volume of mature fine tailings in northeastern Alberta was 830 million cubic metres.\(^ {18}\) That’s enough tailings waste to cover the entire city of Vancouver to a depth of over 7 metres.\(^ {19}\) But regulators have already approved 2.4 million barrels per day of oilsands mining,\(^ {20}\) and each barrel of bitumen produced from mining results in the production of about 1.5 barrels of mature fine tailings.\(^ {21}\) Accordingly, approved minable production would produce 1.4 billion barrels of mature fine tailings\(^ {22}\) and by 2022, oilsands mining is expected to produce enough toxic liquid tailings to submerge New York’s Central Park to a depth of just over 11 feet every month.\(^ {23}\)
**Land disturbance intensity**

Determining the exact impact of each facility requires specific knowledge of where it is being built and the techniques used for forest clearing and construction. However, because any clearing will have some impact on wildlife, the following calculations are based on the total project footprint.

Footprint = the total land disturbance over the life of the project  
Bitumen production = the total expected production associated with that footprint

**In situ**

In situ oilsands extraction requires the development of a dense network of roads, pipelines, wellpads and processing facilities across the boreal forest. A typical deep oilsands project may clear more than eight per cent of the forest in a lease. The forest is fragmented by an average of 3.2 kilometres of roads, pipelines and other disturbances for every single square kilometer of forest. The surface disturbance associated with in situ oilsands development is many times greater than the disturbance associated with conventional oil or gas fields, to which in situ is often compared.\(^{24}\)

Previous analysis by the Pembina Institute has demonstrated that average in situ land use intensity is equal to the project land use intensity (based on footprint area and bitumen production volumes) over the total project lifetime. This equals 1.4 hectares (ha) per million barrels \(^35\) or 1.4x10\(^{-6}\) ha per barrel of bitumen produced. Additionally, academic research has concluded in situ oilsands development has a land use intensity of 1.8x10\(^{-6}\) ha per barrel.\(^{26,27}\) Therefore, for the purposes of this analysis we estimate that in situ oilsands production has an average land use intensity of 1.6x10\(^{-6}\) ha per barrel. It is important to note that this metric measures surface disturbance only, and not habitat fragmentation adjacent to in situ operations.

**Mining**

Mining operations result in the disturbance of large areas to produce bitumen. Before mining can begin, the forest, wetlands and soil are cleared, drained and removed. Rivers and streams are diverted and forests are clear cut, with merchantable timber being harvested and the remainder being piled and burned. In addition, wetlands must be drained and excavated.

There is limited publicly available information on the land use intensity of oilsands mine operations. The recent proposed Shell Jackpine Mine Expansion project has a total lease size of 12,723 hectares,\(^{28}\) a forecasted production rate of 100,000 barrels of bitumen per day\(^{29}\) and a project lifetime of 40 years.\(^{30}\) Total production over the life of the project is therefore 1.5 billion barrels of bitumen. For this project, Shell would disturb 0.094 m\(^2\) of land per barrel of bitumen produced or 9.4 hectares of disturbance per million barrels of production.
By 2022, it is projected that mining and in situ oilsands development will result in the daily clearing of 18.6 hectares of forest, or the equivalent of 34.5 football fields, every day.\textsuperscript{31}
### Summary of extrapolation calculations

<table>
<thead>
<tr>
<th>Impact</th>
<th>Category</th>
<th>Intensity</th>
<th>Unit</th>
<th>OSIP Data</th>
<th>ERCB Data and Projections</th>
<th>Total Approved Projects (November 2, 2012)</th>
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<td></td>
<td>2010</td>
<td>2012</td>
<td>2022</td>
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<td>78,561,985</td>
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<td>Total</td>
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<tr>
<td>Tailings (MFT)</td>
<td>In situ</td>
<td>1.5</td>
<td>bbl/bbl</td>
<td>1,466,370</td>
<td>535,225,050</td>
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*Note: Intensity values are in tonnes/bbl, bbl/bbl, g/bbl, or ha/bbl.*
**METHODS**

**Summary**

We report the average upstream oilsands production impact intensities (per barrel of bitumen or SCO produced) for air emissions, greenhouse gas emissions, water use, and tailings production using publicly available historical data from 2009 onwards.

- Intensity calculations used project-specific data from publicly available sources including: the Oilsands Information Portal (OSIP), Canadian Association of Petroleum Producers (CAPP), National Pollution Release Inventory (NPRI), the Government of Alberta’s Greenhouse Gas Reporting Program, the Energy Resources Conservation Board, and academic papers.
- Project-specific annual emissions data and project-specific annual production volumes (bitumen or synthetic crude oil) were combined for each project and year with data. We weighted intensity averages by the production volumes of the projects included in the calculations for each average. This excludes projects that have already begun operations, but have not yet produced oil (e.g. Imperial Oil’s Kearl mine was excluded (production began in end of March 2013) because it was an outlier that skews the water consumption data upwards considerably. In addition, Nexen’s Long Lake in situ facility was excluded because no other operator has announced plans to replicate this technology approach).
- We used the production volume data reported in the Alberta Oil Sands Information Portal (OSIP) as the denominators for all impact intensity calculations.
- To the best of our knowledge, neither project-specific nor year-specific tailings production volume data is publicly available. Although OSIP reports the area of each tailings lake, this data does not lend itself to quantifying the production volume intensity. The tailings production volume intensity we report is taken from a peer-reviewed academic study.
- Where available, we compared the intensities that we calculated to those that we calculated using industry-wide (i.e., not project-specific) historical impact and production history reported by the Canadian Association of Petroleum Producers (CAPP).
- We used the intensities calculated to extrapolate absolute daily and annual oilsands production impacts associated with 2010 and 2012 actual production, 2022 ERCB production forecasts, and the total production capacity of all oilsands projects that had received regulatory approval as of November 2, 2012 (includes all operating, under-construction, and approved projects).

**Additional Methodological Details**

**Exclusion of Nexen Long Lake In Situ Project**

We considered Nexen’s Long Lake in situ project to be an outlier and excluded it from our calculations of the intensity averages. Sensitivity analyses indicated that inclusion of this project raised the average in situ intensity for all types of impacts with the exception of brackish water use. For brackish water use the inclusion of Long Lake resulted in a slight [3.2%] decrease in the average intensity. To the best of our knowledge, no other planned in situ projects intend to use Nexen’s proprietary OrCrude technology, hydrocracking, and gasification upgrading process to produce Premium Synthetic Crude; thus, extrapolating future absolute impacts from current average impact intensities that include Long Lake would likely result in an upward bias. We therefore excluded Long Lake’s contributions to average impact intensities in order to provide more realistic and/or conservative estimates of future cumulative impacts.
Uncertainty

The impact intensities that we report should be considered averages based on recent industry performance history, not precise forecasts of future impact intensities. Intensities may decrease in the future due to stricter regulations, innovation and implementation of new technologies or increased efficiencies (e.g., increased use of power co-generation or increased recycle-water availability). Conversely, impact intensities may increase in the future as remaining resource deposits become more and more marginal (i.e., requiring more energy and effort to extract a lower-quality resource). It is difficult to quantify whether improvements in performance will outweigh the effect of increasingly marginal resources on the oilsands industry’s environmental performance, especially since unknown future policy and economic scenarios are also likely to be influential variables in this relationship. As such, while the impact intensities we report here are relatively accurate reflections of recent performance history, they are a projection of future impacts based on the assumptions described herein.

Data availability

At the time of writing this report, there was no publicly available historical data for oilsands greenhouse gas emissions or air emissions (NO$_2$, SO$_2$, and PM$_{2.5}$) for the year 2011 or later, and data on the annual volume of tailings produced was not available for any year. Thus, the tailings production intensity we report is taken from another study, and the greenhouse gas and air emission intensities we report are derived from 2009-2010 production and emission data. Oilsands historical water use (fresh and brackish) data was available for the year 2011; the water use intensities we report are derived from 2009-2011 production and water use data in order to reflect the most recent oilsands water use trends.

Greenhouse gas emissions associated with cogeneration of electricity

Some oilsands projects use a combined process to generate steam and electricity on site, whereas other projects purchase electricity from the Alberta electricity grid and utilize on-site boilers for steam. The combined process is known as cogeneration or combined heat and power. Facilities that employ cogeneration typically produce more electricity than they need and sell the surplus into the grid for use elsewhere. The inclusion of cogeneration emissions therefore overestimates the average GHG emission intensities associated with oilsands production in those facilities. Conversely, excluding the GHG grid emissions emitted by external providers of electricity to oilsands projects that do not employ cogeneration (instead having standalone boilers and purchasing power from Alberta’s grid) results in an underestimation of GHG emission intensities associated with oilsands production from non-cogeneration facilities. Because of this complexity, we chose to use full facility emissions for all projects in our analyses of GHG and air emissions. Thus, we neither credited projects for cogeneration contributions to the grid nor penalized projects for electricity consumed from the grid.

Full data tables are available upon request.
Endnotes


7 The RCE 2010 progress report notes that about 0.6 barrels of fresh water was used to produce each barrel of oil produced from conventional oil operations in Alberta in 2010. Responsible Canadian Energy, *2010 Progress Report*. http://www.rc2010.ca/western-canada/water/water-usage/


10 A typical bathtub contains approximately 160 litres of water.

11 In a comparison of production emissions only, the per-barrel greenhouse gas emissions associated with oilsands extraction and upgrading are estimated to be 3.2 to 4.5 times as high as than conventional crude oil produced in Canada or the United States. National Energy Technology Laboratory, *Development of Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels*, DOE/NETL-2009/1346 (2008), 12. http://www.netl.doe.gov/energy-analyses/pubs/NETL LCA Petroleum-Based Fuels Nov 2008.pdf


13 Projected 2022 annual GHG emissions is 108,521,651 tonnes. The average U.S. passenger vehicle emissions in 2010 was 4.8 tonnes CO$_2$e per year. U.S. Environmental Protection Agency, "Calculations and References." http://www.epa.gov/cleanenergy/energy-resources/rels.html


16 Mining tailings production intensity refers to what’s known as “mature fine tailings”. The sand particles in tailings settle to form a stable deposit fairly quickly, while the finer clay particles take decades to settle (these are known as fluid fine tailings). In three to five years, the fluid fine tailings will concentrate to about 30 or 35 per cent solids at which time they are referred to as mature fine tailings (MFT). Because these mature tailings don’t settle out and cannot be reclaimed without substantial processing, more and larger tailings ponds have been required over the years as production has increased.


The City of Vancouver is 114.9 km$^2$ in size or 114,900,000 m$^2$. The volume of tailings (m$^3$) was divided by the surface area to find a depth of 7 metres.

This value is approved oilsands production only. However, should industry and government projections be accurate, production levels of this magnitude may be realized by 2025. Oilsands Review, “Statistics: Oilsands Production.”

Mikula, “Advances in oil sands tailings handling.”

2.4 million barrels of mineable production/day x 1.57 bbl of MFT/bbl of bitumen = 3.77 million barrels of MFT/day. 3.77 million barrels of MFT per day is equivalent to 1.4 billion barrels of MFT per year.

Area of New York’s Central Park is 339 ha, or 3,339,000 m$^2$. Daily production of tailings in 2022 is projected to be 2,405,849 barrels or 382,500 m$^3$, which gives a covering of 0.115 m per day or 3.45 metres (11.3 feet) per month.


In situ land intensity average value of 0.115 m$^2$/m$^3$ SCO (from Jordaan et al.) is equivalent to 0.0000018 ha per barrel. According to CAPP, in situ production in 2011 is 833,000 barrels per day. 833,000 barrels per day*0.0000018 ha per barrel results in 1.5 ha of land disturbance per day. This is approximately equal to 3 football fields per day.


"Application for Approval of the Jackpine Mine Expansion Project," Vol. 1, P-iii.

Area of an American football field = 120 x 53.3 yards = 6,396 sq yards = 0.54 hectares. http://en.wikipedia.org/wiki/American_football