Catalogue no. 16-002-X
ISSN 1913-4320

EnviroStats

Canada’s shifting sands: Oil production, distribution and implications, 2005 to 2014

by Lawrence McKeown with Corben Bristow and Anthony Caouette
Environment, Energy and Transportation Statistics Division

Release date: July 12, 2016

Statistics Canada Statistique Canada

Canada

How to obtain more information

For information about this product or the wide range of services and data available from Statistics Canada, visit our website, www.statcan.gc.ca.

You can also contact us by

email at STATCAN.infostats-infostats.STATCAN@canada.ca

telephone, from Monday to Friday, 8:30 a.m. to 4:30 p.m., at the following toll-free numbers:

- Statistical Information Service 1-800-263-1136
- National telecommunications device for the hearing impaired 1-800-363-7629
- Fax line 1-877-287-4369

Depository Services Program

- Inquiries line 1-800-635-7943
- Fax line 1-800-565-7757

Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable and courteous manner. To this end, Statistics Canada has developed standards of service that its employees observe. To obtain a copy of these service standards, please contact Statistics Canada toll-free at 1-800-263-1136. The service standards are also published on www.statcan.gc.ca under "Contact us" > "Standards of service to the public."

Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Standard table symbols

The following symbols are used in Statistics Canada publications:

. not available for any reference period
.. not available for a specific reference period
... not applicable
0 true zero or a value rounded to zero
0^s value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p} preliminary
^{r} revised
x suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E} use with caution
F too unreliable to be published
* significantly different from reference category ($p < 0.05$)

An HTML version is also available.

Cette publication est aussi disponible en français.

Canada's shifting sands: Oil production, distribution and implications, 2005 to 2014

by Lawrence McKeown with Corben Bristow and Anthony Caouette, Environment, Energy and Transportation Statistics Division

Highlights

- Oil production in Canada increased by over 50% from 2005 to 2014 with crude bitumen and synthetic crude accounting for almost all of the growth.
- In 2014, Canadian railways shipped over 185,000 rail cars containing fuel oils and crude petroleum; three times the number shipped in 2005.
- Since 2005, pipeline and rail accidents have tended to reflect broader economic trends, but notable spills have clearly demonstrated some of the risks of the oil industry.
- Largely driven by oil sands expansion, the oil and gas sector accounted for over one quarter (26%) of Canada's 732 megatonnes of greenhouse gas (GHG) emissions in 2014.

Shifting sands

In 2008, Canada's energy sector appeared to have reached a turning point. The price of crude oil had steadily increased since 2002, causing concern about the impact of higher prices on Canadian consumers.[1] Despite the vast reserves of crude oil in Canada, imports continued to supply almost half of crude oil refined domestically. That same year however, higher oil prices also helped to catapult energy into Canada's largest export earner, surpassing motor vehicles and parts.

By 2015, energy's run as Canada's biggest export ended with declining oil prices becoming a cause for concern.[2] The world was grappling with an over-supply of oil that stemmed from changing demand and from the supply of non-conventional crudes. In Canada, growing oil production has altered distribution channels to refineries and markets. Together, these changes may also have consequences for the environment.

This article examines trends from 2005 to 2014 in Canadian oil production and distribution, as well as some possible implications. It focuses on two potential environmental concerns arising from these trends: the risk of accidents during transport and higher greenhouse gas (GHG) emissions related to overall industry growth and the increased extraction from non-conventional reserves.[3]

1. Cross, P. and Ghanem, Z., 2008, "Over a barrel? Canada and the rising costs of energy," *Canadian Economic Observer*, Statistics Canada Catalogue no. 11-010-X, Vol. 21, no. 8.
2. Statistics Canada, "Canadian international merchandise trade, July 2015," *The Daily*, September 3, 2015.
3. There are others; for example, open-pit mining can damage boreal forests and separating the oil and sand at the mine site uses large quantities of water and creates enormous tailings ponds.

What you should know about this study

Data used for this article are from the environment, energy and transportation statistics programs at Statistics Canada, with corresponding CANSIM table numbers provided. Other data sources include Transport Canada's Dangerous Goods Accidents Information System, the Transportation Safety Board's Occurrence Database System and Environment and Climate Change Canada's National Inventory Report of Greenhouse Gas Sources and Sinks in Canada.

Definitions

Crude oil – A naturally occurring hydrocarbon formed by decaying organic material in the ground under intense heat and pressure for millions of years. Crude oil ranges in viscosity based on its hydrocarbon composition.

Class 3 Dangerous Goods – Flammable and combustible liquids, which include crude petroleum, is one of nine classes of dangerous goods defined by the *Transportation of Dangerous Goods Act, 1992*.

Crude bitumen – The thickest, heaviest form of crude oil that must be either heated or diluted before it can flow. A conventional oil refinery has to be modified to receive crude bitumen or else additional processing is required at an upgrading facility.

Diluent – A fluid used to reduce the viscosity of heavier crudes, such as bitumen, to allow them to flow in a pipeline. Condensate is the most commonly used diluent in transporting crude oil in western Canada.

Heavy crude – With a density of 900 kg/m^3 or greater, this crude requires a diluent to allow pipeline flow. Although it can be refined into lower priced products such as asphalt or heavy fuel oil, additional refining is required to create higher-value products.

Light and medium crude – With a density of less than 900 kg/m^3, light to medium crudes flow freely at room temperature. In general, lighter crudes command higher prices as they can be more easily refined to produce higher demand products such as motor gasoline.

Synthetic crude – The output from upgrading extra heavy crude or bitumen from the oil sands; this intermediate form of crude can be sent to conventional refineries for further processing into higher-value products.

One U.S. barrel of oil is equivalent to 0.15891 cubic metre (m^3).

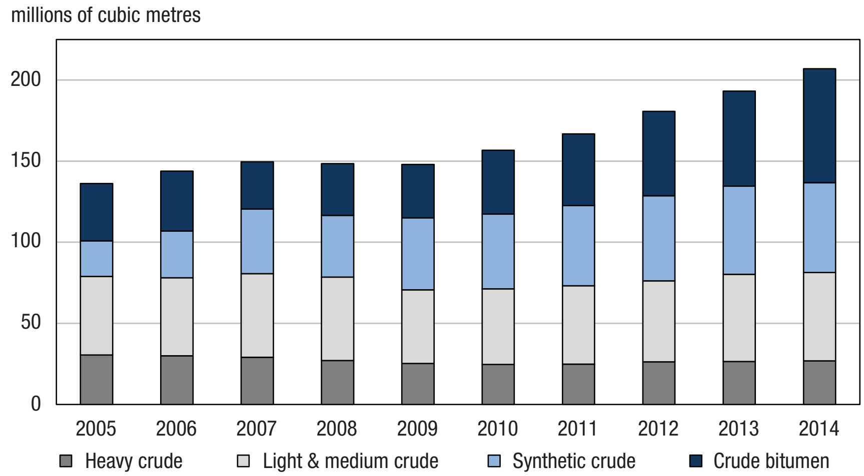
Production: A shift to non-conventional oil

Canada's oil industry has evolved dramatically since the first well was drilled over 150 years ago in Oil Springs, Ontario. In 1947, the discovery of vast oil reserves near Leduc, Alberta helped to fundamentally transform the Albertan economy. While crude bitumen from the oil sands was first upgraded in Alberta almost 50 years ago, upgrading capacity has been steadily and significantly added ever since. During the last 20 years, oil reserves off the coast of Newfoundland and Labrador have been developed. And more recently, Saskatchewan's Bakken fields have become commercially viable as a result of rising prices and technological improvements in extraction methods.

Crude oil is a mixture of hydrocarbons trapped in an underground reservoir. Conventionally, it is extracted by drilling a well into the reservoir and the oil is either pumped or the natural pressure is high enough for it to flow to the surface. With technological improvements in exploration and extraction, other reserves are being tapped: conventional crude by horizontal drilling which pumps liquids ("fracking fluids") in order to fracture the geological formation, facilitating the flow, and non-conventional crude, by extracting in situ oil sands using steam to help crude bitumen flow. However, these newer methods involve higher production costs and may have greater environmental impacts from production (i.e., more energy intensive extraction) and from distribution (i.e., more remote locations).

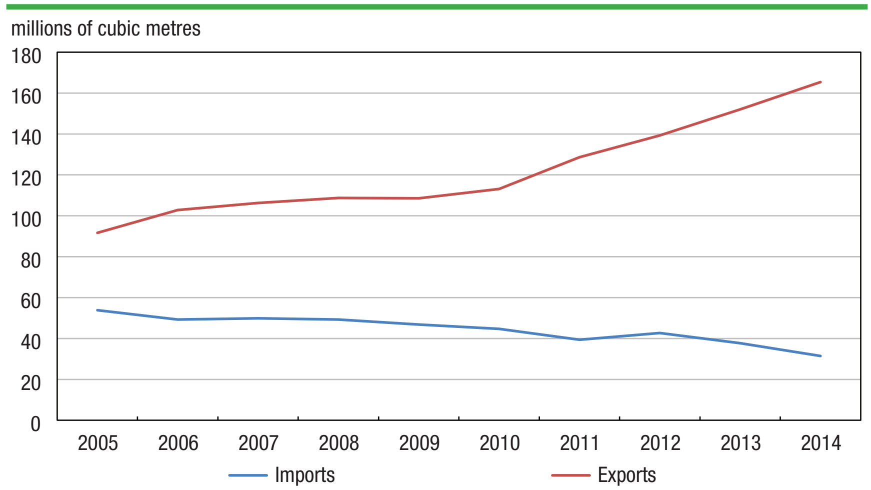
Despite declining conventional reserves, rising world prices and technological advances in extraction spurred a 50% growth in Canadian crude production from 2005 to 2014 (Chart 1). Indeed, 2014 was the fifth consecutive year in which crude oil accounted for the largest share of primary energy production in Canada, after replacing natural gas.[4] However, the aggregate contribution of light, medium and heavy crude production declined from almost 60% of the total in 2005 to under 40% by 2014. Growth in the extraction of non-conventional crude bitumen and the production of synthetic crude accounted for most (97%) of the increase.

Chart 1
Total crude production in Canada, 2005 to 2014



Source: Statistics Canada, CANSIM table 126-0001.

Chart 2
Canadian crude oil imports and exports, 2005 to 2014



Source: Statistics Canada, CANSIM table 126-0001.

Distribution: Delivering oil to market

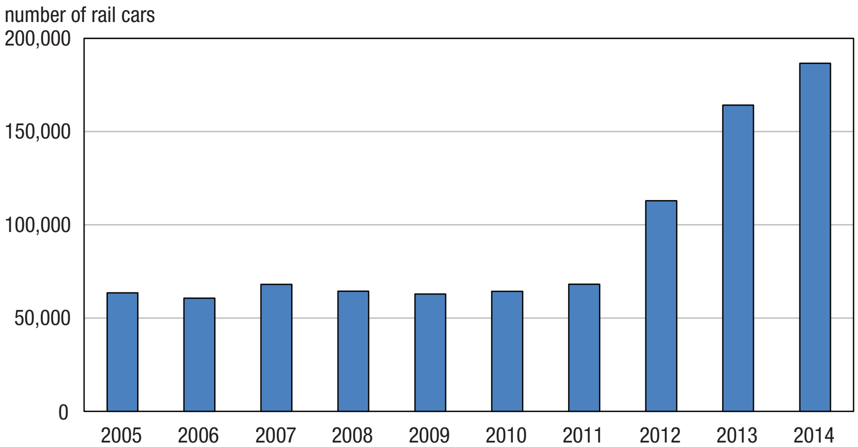
In its raw form, crude oil has limited economic value and is shipped to an oil refinery for separation into a range of products such as motor gasoline, aviation fuel, asphalt and propane. The outputs from a refinery partly depend on the type of crude used as input. For example, a lighter crude oil produces a larger proportion of lighter and higher-value products such as motor gasoline. Although some oil refineries are located in Western Canada, the majority of Canadian crude is processed in refineries located close to eastern markets that are equipped to refine imported oil, which generally consists of lighter crudes. And Canada's pipeline network was designed to serve this refining capacity.

Increasingly, more oil is extracted from non-conventional reserves, often in remote areas. In particular, crude bitumen from the oil sands is an extra-heavy crude that is characterized by a higher viscosity. A diluent must be added so the bitumen can be pumped through pipelines, adding to transportation costs. And in theory, a heavier raw material such as crude bitumen should be processed closer to the source of extraction. Bitumen often requires treatment in an upgrader facility to remove carbon through coking and/or to add hydrogen. This treatment creates a higher-value synthetic crude that can be more easily shipped by pipeline for conventional refining.

During the study period, the growth in domestic crude oil production resulted in higher levels of exports, jumping 80% from 2005 to over 165 million cubic metres (m^3) in 2014 (Chart 2). Over the same period, imports declined, falling 42% from

4. Statistics Canada, "Energy supply and demand, 2014," *The Daily*, December 10, 2015.

Chart 3
Railway carloadings, fuel oils and crude petroleum, Canada, 2005 to 2014



Source: Statistics Canada, CANSIM table 404-0002.

about 54 million m^3 in 2005 to just over 31 million m^3 in 2014. Despite these changes, refining capacity has remained more or less fixed both in scale and in location. Although there appears to be insufficient mainline pipe for the growing volume of oil production in the long term, in the short term more crude oil was shipped to markets in one of two ways.

First, more oil was pumped by enhancing capacity of the existing pipeline network. From 2005 to 2014, the total net pipeline deliveries of crude oil increased by 58% or roughly 117 million m^3.

More than half of this increase was accounted for by exports, enabled by a combination of key new pipeline segments[5] along with selected line conversions (i.e., natural gas to oil). Another significant portion of this overall volumetric increase was for net deliveries to plants, enabled by higher pipeline throughput using more powerful pumps as well as by both line conversions and line reversals that change the direction of flow.[6]

Second, another way of shipping oil, accounting for part of the increase in deliveries from 2005 to 2014, is by rail. One indication is that pipeline shipments of crude oil classified as "net deliveries to other," which includes rail loading facilities, increased from roughly 8 million m^3 in 2005 to almost 22 million m^3 by 2014. The movement of crude oil by rail is now viewed as a short-term solution that is necessary given insufficient pipeline capacity. Indeed, the number of filled tank cars loaded with "fuel oils and crude petroleum" shipped by Canadian railways tripled from 2005 to 2014, with the growth occurring after 2011 (Chart 3).[7]

Environmental implication: Risk of accidents

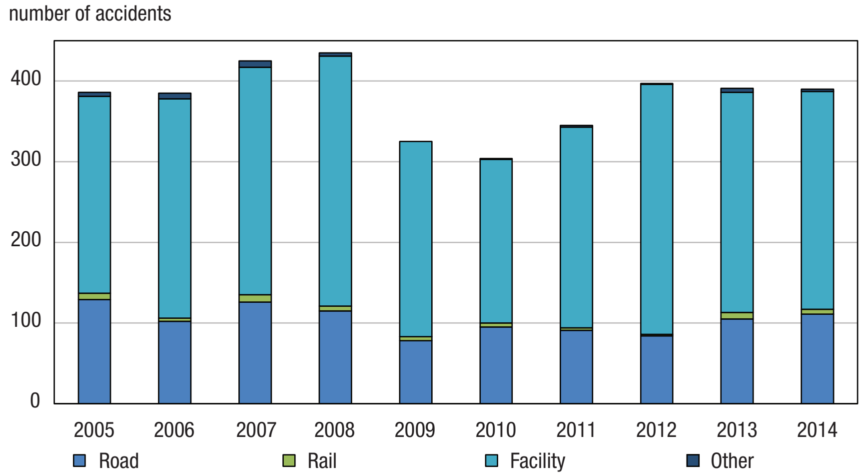
Is there an increased risk when shipping a greater volume of oil to refineries or export markets? The recent growth of Canada's oil production has spawned debate on the most appropriate method of shipping crude, often pitting pipeline construction against shipping more by rail.[8] There are two data sources that are used to help illuminate the safety issue: (1) Transport Canada's Dangerous Goods Accident Information System (DGAIS) and (2), the Transportation Safety Board's (TSB) Rail and Pipeline Occurrence Database Systems.

The Transportation of Dangerous Goods regulations (section 8) require handlers of dangerous goods to report accidents to Transport

5. In 2010, Phase I of the Keystone pipeline connected Hardisty, Alberta with Patoka, Illinois via Steele City, Nebraska. In 2011, Phase 2 extended the pipeline from Steele City to Cushing, Oklahoma. Both phases allowed for an increase in Canadian crude oil exports to the U.S. Approval for the Keystone XL (Phase 4), to connect Hardisty to Steele City more directly with a larger diameter pipe, was indefinitely delayed by U.S. President Obama on November 7, 2015.
6. Previously, Enbridge's Line 9 pumped up to 240,000 barrels per day (bpd) of imported crude westward from Québec to Sarnia, Ontario. After a shutdown in December of 2015, flow was reversed allowing up to 300,000 bpd to be pumped eastward from Sarnia to refineries in Ontario and Québec.
7. The Standard Classification of Transported Goods (SCTG), used by the monthly Railway Carloadings Survey, defines "Fuel oils and crude petroleum (including bituminous mineral oil and tar sands)."
8. See Senate of Canada, 2013, *Moving Energy Safely: A Study of the Safe Transport of Hydrocarbons by Pipelines, Tankers and Railcars in Canada*, Standing Committee on Energy, the Environment and Natural Resources; Cairns, M., 2013, Rail Safety in Transporting Dangerous Goods in Canada. *Canadian Transportation Research Forum, Policy Brief* (November); Winter, J., 2014, "Safety in Numbers: Evaluating Canadian Rail Safety Data," *SPP Communiqué*, Vol. 6, no. 2, University of Calgary, School of Public Policy; Green, K. and T. Jackson, 2015, "Safety in the Transportation of Oil and Gas: Pipelines or Rail?" *Fraser Institute, Research Bulletin* (August); and Oliver Wyman Companies, 2015, *Canadian Crude Oil Transportation: Comparing the Safety of Pipelines and Railways*, prepared for the Railway Association of Canada (December).

Canada;[9] DGAIS data are then disseminated by Statistics Canada (CANSIM tables 409-0001 to 409-0010). The total number of reportable dangerous goods accidents dipped following the economic downturn of 2008 (Chart 4). Most reportable accidents of dangerous goods occur during handling at facilities (i.e., terminals, ports and warehouses) rather than in transit. Of those occurring in transit, a vast majority happen during road transport, while those by rail fluctuated between 1% and 2% of the total.

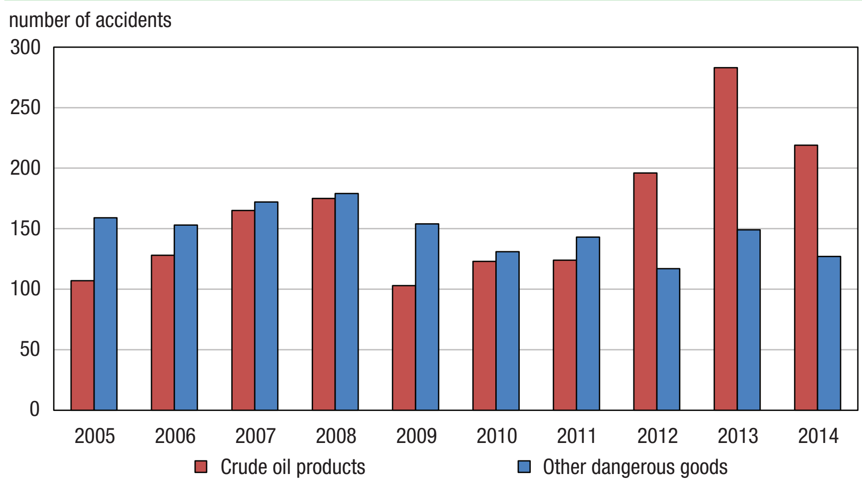
Chart 4
Reportable dangerous goods accidents by mode, Canada, 2005 to 2014



Source: Transport Canada, CANSIM Table 409-0001.

Crude oil is usually transported as a Class 3 (Flammable Liquids) dangerous good, which requires the reporting of accidents involving spills of 200 litres or more. Accidents involving crude oil products fell after the 2008 economic downturn but have increased steadily since and now exceed those involving all other dangerous goods (Chart 5). As previously noted, the bulk of such accidents occur in facilities such as "bulk storage facilities." In 2014 for example, about 70% of all dangerous goods accidents occurred in a facility with the top initiating events reported as "improper loading / unloading and handling" (32%), "overfill" (25%) and "defective fittings, valves and covers" (24%).

Chart 5
Dangerous goods accidents by commodities, Canada, 2005 to 2014



Source: Transport Canada, CANSIM Table 409-0006.

Another source of information is the TSB regulations, pursuant to the *Canadian Transportation Accident Investigation and Safety Board Act*. They require the operator of a pipeline to report selected occurrences (e.g., release of product, injury or damage) to the Board. From 2005 to 2014, there were an average of 55 oil pipeline occurrences each year with 84% of them resulting in a release of crude petroleum, condensates, or a refined product (Chart 6). The average, non zero volume of product released was 36 m^3 per occurrence. However, this value may not reflect the actual amount

9. Regulations, pursuant to the 1992 *Transportation of Dangerous Goods Act*, require that "any person who has charge, management or control of a means of containment shall report to Transport Canada any release or anticipated release, loss or theft of dangerous goods that is or could be in excess of a quantity specified, by regulation, from the means of containment if it endangers, or could endanger, public safety."

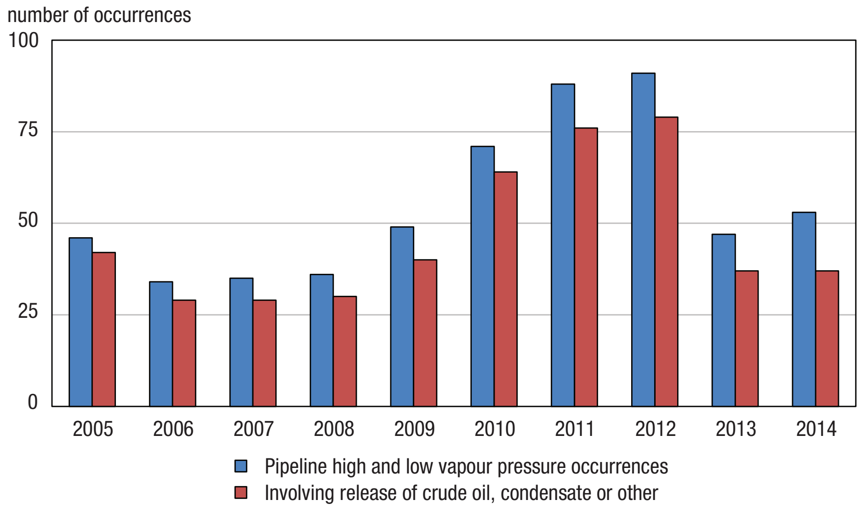
released since mandatory reporting of the quantity released has only been required since July of 2014.[10]

In addition to the occurrences reported to the TSB, there have also been some notable pipeline accidents, both after the study period and by a Canadian operator outside of Canada.[11]

Similarly, operators of rolling stock and rail are required to report a railway occurrence to the TSB. Since 2014, a derailment occurs "any time at least one wheel of rolling stock comes off the normal running surface of the rail." From 2005 to 2014, there was an annual average of 780 train derailments in Canada with more than 85% occurring on non-mainline tracks (branch lines, sidings, railyards). On average, less than one third (31%) of total derailments involved trains with rail cars carrying dangerous goods, and only a small number resulted in a release (Chart 7).

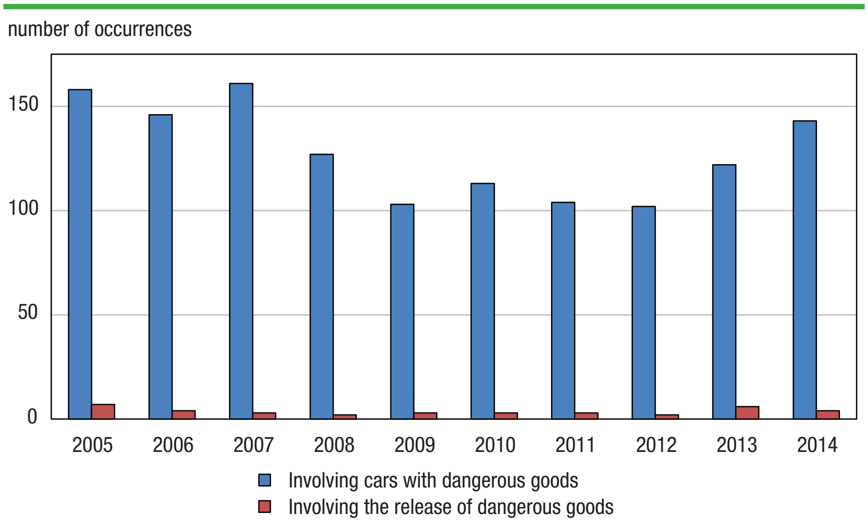
In 2013, there were six derailments that resulted in a release of dangerous goods. However, one of the six involved a major mainline derailment of a Montreal, Maine & Atlantic Railway train during July in the Quebec town of Lac Mégantic. This spill released a large quantity of crude oil that resulted in an explosion, fire, evacuation, major damage to the surrounding community and 47 fatalities. Since that catastrophic event, the policy debate on the merits of moving

Chart 6
Oil pipeline occurrences, Canada, 2005 to 2014



Source: Transportation Safety Board, Pipeline Occurrence Database System.

Chart 7
Derailment occurrences involving dangerous goods, Canada, 2005 to 2014



Source: Transportation Safety Board, Rail Occurrence Database System.

10. Of the 463 oil pipeline occurrences from 2005 to 2014 involving release of a product, 70% of filings either could not or did not quantify the amount released. As of 2014, the TSB Regulations for Pipeline Occurrences (4 (2) (h)) require "a list of commodity contained in or released from the pipeline and an estimate of the volume of commodity released and recovered."

11. For example, in July of 2015, a Nexen Energy ULC pipeline was discovered to have released about 6,000 m^3 of a bitumen by-product over 16,000 m^2 of wilderness south of Fort McMurray, Alberta. And in July of 2010, Enbridge's 41-year-old 6B pipeline ruptured in Michigan, leaking 19,500 barrels of crude oil of which about 8,500 spilled into the Kalamazoo River.

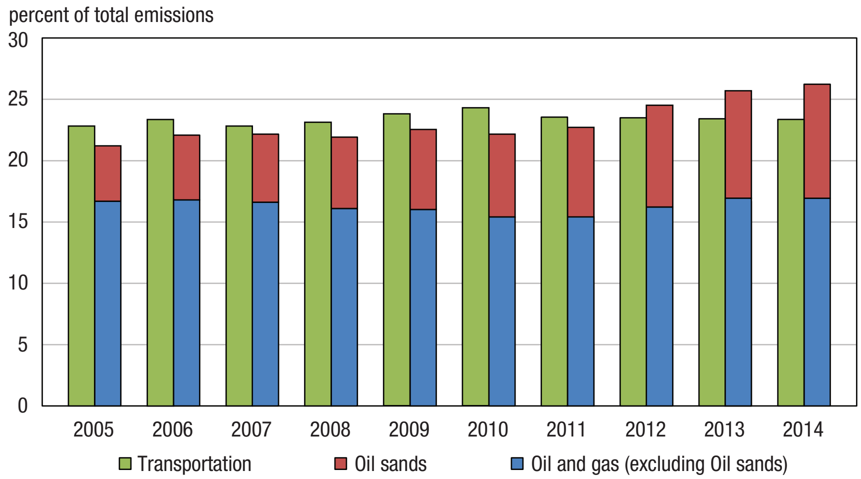
crude oil by rail versus building more pipelines has intensified (see footnote 8).

Environmental implication: Higher emissions

The steady increase in world oil prices from about 2002 into 2014 drove technological advances in extraction and made non-conventional reserves more commercially viable. Again, this served to change the composition of oil production in Canada. And measured along the entire supply chain (i.e., extracting, transporting, refining, marketing, and combusting), some types of heavy crude from non-conventional reserves have been estimated to emit about one and a half times the kilograms of carbon dioxide (CO_2) equivalent per barrel than did a lighter crude oil.[12]

Canada reported an increase of 85 megatonnes in GHG emissions between 1990 and 2014 in the oil and gas sector, resulting from a higher level of crude oil production and an expansion of the oil sands.[13] Allocating emissions according to economic activity or sector, oil and gas surpassed transportation in 2012 as the largest contributor to GHG emissions in Canada (Chart 8). In 2014, the total oil and gas sector contributed over one quarter (26.2%) of Canada's emissions, with the oil sands portion contributing 9.3%.

Chart 8
Share of total greenhouse gas emissions by selected sectors, Canada, 2005 to 2014



Source: Environment and Climate Change Canada, 2016, *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada*, part 3, p. 41.

As such and given the volume of Canada's oil exports (Chart 2), the recent expansion of the oil and gas sector contributes significantly to domestic GHG emissions associated with the production of goods for export. In 2012, "Conventional and synthetic crude" and "Crude and diluted bitumen" were estimated to account for a combined 28% of the 295 megatonnes of GHG emissions embedded in Canadian commodity exports.[14]

The recent decline of oil prices continues to affect the Canadian energy sector. However, the International Energy Agency (IEA) asserts that, while the overall oil supply from most non-OPEC countries could be headed for a significant drop, Canada's output rose in 2015 (CANSIM 126-0001) and is expected to rise again in 2016.[15] Therefore, the larger policy discussion on the role of energy in the Canadian economy is poised to continue, including concerns over the risk of accidents during delivery (i.e., pipelines versus rail) and the energy sector's contribution to GHG emissions.

12. A type of Canadian synthetic crude was estimated to emit over 800 kg of CO_2 equivalent per barrel compared to under 500 kg for a barrel of Canadian Hibernia (see Gordon, D., Brandt, A., Bergerson, J. & Koomely, J., 2015, *Know Your Oil: Creating a Global Oil-Climate Index*, Washington: Carnegie Endowment for International Peace. p. 36).
13. While the average intensity of GHG emissions per barrel of non-conventional oil was declining from 1990 to 2014, there were considerably more barrels produced (see Environment and Climate Change Canada, 2016, National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada – Executive Summary, p. 10).
14. Statistics Canada, CANSIM table 153-0129 and custom tabulation derived therefrom.
15. The IEA's June 2016 *Oil Market Report* forecasts that the prolonged and extensive shutdowns caused by wildfires in Alberta are expected to erase previously anticipated supply growth this year with total output now expected to be largely unchanged from 2015; however, supply growth will continue in 2017.