

IHS ENERGY

Crude by Rail

The new logistics of tight oil and oil sands growth

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SPECIAL REPORT

Canadian Oil Sands Dialogue

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About this report

Purpose. The Great Revival in North American crude oil production has occurred so rapidly that pipeline infrastructure has struggled to catch up with supply growth. “Crude by rail” has become a key part of the system to ship oil from producing areas to refineries. As the volume of crude oil moving by rail has increased, so have safety concerns. The US and Canadian governments are responding with new rules to improve safety. This report explores the evolution and outlook for movements of crude by rail in North America; the safety of these movements; and the implications of new policies aimed at enhancing the safety of crude by rail.

Context. This report is part of a series from the IHS Canadian Oil Sands Energy Dialogue. The dialogue convenes stakeholders to participate in an objective analysis of the benefits, costs, and impacts of various choices associated with Canadian oil sands development. Participants include representatives from governments, regulators, oil and gas industry, academics, pipeline operators, refiners, and nongovernmental organizations. This report and past Oil Sands Dialogue reports can be downloaded at www.ihs.com/oilsandsdialogue.

Methodology. IHS conducted our own extensive research and analysis on this topic, both independently and in consultation with stakeholders. This report was informed by multistakeholder input from a focus group meeting held in Ottawa, Ontario, on 3 April 2014 and participant feedback on a draft version of the report. IHS has full editorial control over this report and is solely responsible for the report’s content (see the end of the report for a list of participants and the IHS team).

Structure. This report has four parts and an appendix:

- Part 1: Introduction
- Part 2: Moving crude by rail
- Part 3: The history and outlook for crude by rail
- Part 4: Safety of moving crude oil by rail
- Part 5: Evolving policy

Crude by Rail

The new logistics of tight oil and oil sands growth

Key implications

Railroad transportation has become an enabler of production growth in North America because pipeline capacity has struggled to catch up. But several accidents have raised safety concerns about the increasing role of “crude by rail.” In response, new safety rules have been proposed that could affect the movement of crude by rail. This report explores the evolution of and outlook for crude by rail in North America, the safety of these movements, and the potential implications of new safety rules.

- **Rail transport has become an enabler of crude oil production growth in North America.** In the absence of sufficient pipeline capacity, increasing volumes of crude have been shipped to market by rail. Since 2009, crude-by-rail shipments have increased from 20,000 barrels per day (b/d) to an anticipated annual average of 1.1 million barrels per day (MMb/d) for 2014—about 9% of North American production.
- **The peaking of crude by rail is linked to production growth and the timing of new pipeline capacity.** IHS expects crude by rail to peak between 2015 and 2016 at approximately 1.5 MMb/d—over 10% of North American production. However, should production growth exceed expectations or pipeline projects encounter delays, crude movements by rail could be higher.
- **Rail is here to stay.** Even with new pipeline capacity, we expect movements of crude by rail to continue—exceeding 900,000 b/d out to 2020. The ability of rail to reach refineries unconnected by pipeline will make rail a key and enduring element of the North American oil transport system.
- **Accidents involving rail transport of hazardous material, which includes ethanol, crude oil, and other materials, have declined since the early 1980s.** Despite a nearly threefold increase in the transport of hazardous materials since 1980, over the past five years (2009–13) accidents in which hazardous material was released were a third of the 1980–85 total.
- **Regulatory changes to improve safety, such as speed reductions and more robust tank cars, may also contribute to greater traffic.** Lower speeds and heavier cars (with lower capacity) could lead to demand for more carloads to transport the same volume of crude. This is contributing to some uncertainty over the availability of tank cars, the cost of crude by rail, and the potential for congestion and capacity impacts.

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Part 1: Introduction

Shipments by rail were the dominant form of transport in the early decades of the North American oil industry.¹ However, rail was supplanted by the growth of pipelines. As recently as 2009, rail shipments constituted a very small share of oil transit, delivering just over one-tenth of 1 percent of all crude oil consumed by refineries in North America that year.

But railroads maintained their role as the backbone of the North American economy. They service many sectors, including petrochemicals, agriculture, mining, forestry, overall manufacturing, and consumer goods. On a ton-mile basis, or the distance that freight is moved, rail accounted for two-thirds of all freight movements in the United States in 2012. In 2013, in excess of 2 billion tons of goods were moved by rail in the continental United States.²

In 2009, the great revival of American oil production began which, combined with already steadily growing output from Canada, led to immediate and growing needs for capacity to ship more oil. The existing pipeline network was unable to keep pace with production growth, nor was it all well-placed for the new production. The North American rail system offered immediate and flexible capacity along with an extensive network.

In less than five years, the volume of crude shipped on North American railroads has grown tremendously. In 2009, about 20,000 barrels per day (b/d) (12,000 carloads per year) of crude moved by rail.³ In 2013, over 950,000 b/d (about 540,000 carloads per year) were estimated to have been transported by rail—nearly 9% of North American production. As the volume of crude oil moving by rail has increased, a number of accidents have been reported, increasing safety concerns. In a few of these events, explosions occurred, including a tragic accident in Lac Mégantic, Québec, in July 2013, which claimed the lives of 47 people. These accidents have captured the attention of the public, crude oil producers, railroads, and governments in Canada and the United States.

With even greater movements of crude by rail expected, regulators are seeking ways to enhance the safety of this form of transport. This effort also encompasses ethanol, of which 250,000 b/d (about 390,000 carloads) were shipped by rail in 2013.⁴ A number of measures have been proposed on both sides of the border that could affect future movements.

Tight oil and oil sands are referenced throughout this report. For additional background information on these two sources of supply growth, see the text box “Primer: Oil sands and tight oil.”

1. North America is used throughout this report to mean Canada and the United States.

2. Source: US Department of Transportation, “Freight Facts and Figures 2013,” www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/13factsfigures/pdfs/fff2013_highres.pdf, accessed 13 November 2014.

3. IHS Transearch North American freight flow database. Data include only movements by rail intersecting the continental United States. Wholly inter-Canadian movements are not captured. For more information see <http://www.ihs.com/products/global-insight/industry/commerce-transport/database.aspx>.

4. IHS Transearch North American freight flow database.

Primer: Oil sands and tight oil

The two pillars of the Great Revival of North American crude oil production are US tight oil and the Canadian oil sands.

US tight oil

Tight oil is sourced from rocks of low permeability and porosity. Oil is produced by drilling horizontal wells into the rock formations and fracturing them through hydraulic stimulation. This process opens pathways in the rocks that allow hydrocarbons to be recovered.

To date, the most prolific producing tight oil areas have been the Bakken (including the Three Forks) Formation in North Dakota and the Eagle Ford Shale and Permian Basin in Southwest Texas. In 2013 these regions accounted for over 80% of US tight oil production.*

Canadian oil sands

Oil sand is a naturally occurring mixture of sand, clay, water, and bitumen. In its natural state, raw bitumen is solid at room temperature and cannot be transported by pipeline. To be transported by pipeline, bitumen must be either blended with lighter hydrocarbons or converted into a light crude oil, called synthetic crude oil (SCO).

- **SCO.** SCO is produced by upgrading bitumen (by either removing carbon or adding hydrogen) from a heavy crude oil into a lighter crude oil. SCO resembles light, sweet crude oil, typically with a density of less than 876 kilograms (kg) per cubic meter (or an API gravity greater than 30°).
- **Bitumen blends.** To meet pipeline requirements, bitumen is diluted with lighter hydrocarbons (often natural gas condensate, which is a pentane plus hydrocarbon) into a bitumen blend. The blend density is between 923 and 940 kg per cubic meter (20–22°API), making it comparable to other heavy crudes, such as Mexican Maya. A common bitumen blend is “dilbit”—short for diluted bitumen—which is typically about 70% bitumen and 30% lighter hydrocarbons. Alternative blends known as “railbit” and “neatbit” are increasingly being discussed for rail transport. Railbit is a blend of 12–18% diluent, and neatbit is a nearly pure bitumen product containing about 1–2% diluent.

*Bakken Three Forks Formation extends into Montana and Saskatchewan.

Part 2: Moving crude by rail

The components of moving crude by rail from field to refinery

Compared with pipelines, the transport of crude by rail generally involves more parties. For crude by pipeline, these typically include a shipper, which contracts for space on a pipeline; a pipeline operator, which transports the crude; and a receiver, typically a refiner, which takes receipt on the other end. The parties typically involved in the transport of crude by rail are described below and illustrated in Figure 1.

- **Shipper.** Crude oil is transported from the field to a loading terminal by pipeline and/or truck. Shippers can be crude oil producers, refiners, or third-party marketing agents.
- **Loading/unloading terminals.** Terminal operators are responsible for the proper loading or unloading of tank cars. It is the responsibility of the terminal operator to ensure that crude oil is loaded into appropriate tank cars (in accordance with hazardous material regulations) and that the cars are properly labeled (so first responders are aware of the contents). Crude oil loading terminals are typically owned by third-party companies but can also be owned by producers or refiners.

- **Tank cars.** Tank car owners are responsible for ensuring that their cars meet regulatory standards. About 75% of the cars in North America are owned by third-party leasing companies. Shippers, receivers, and railroads also own tank cars.
- **Railroads.** The railroads are responsible for the safe transport of crude to market. This requires that they ensure that their tracks and equipment are properly maintained.
- **Receiver.** Refiners receive the crude, either directly or from an unloading terminal operated by a third party.

Two key components of crude by rail are the railroads and the tank car. These are discussed below in more detail.

The North American railroads

In North America, freight railway companies are classified as either Class 1 or short-line railroads. Although the distinction is technically based upon revenue, with Class 1 being the larger operation, for simplicity they can be considered as long-haul versus short-haul.⁵

The North American freight rail industry consists of seven Class 1 railways and over 500 short-line operations. Industry operations can be loosely divided by geography. In Canada, there are two transcontinental networks, those of Canadian Pacific Railway (CP) and the Canadian National Railway (CN), as well as over 50 short-line operations. Both CP and CN have significant operations in the United States and therefore qualify as Class 1 on both sides of the border.

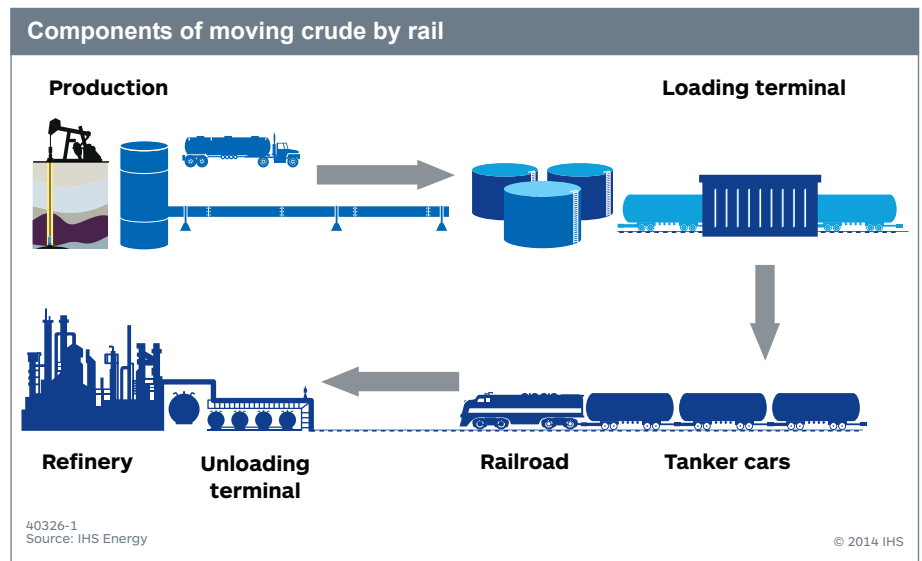
In the United States, freight rail is dominated by four large Class 1 rail networks. Two operations are focused in the East—Norfolk Southern and CSX Corporation—and two in the West—Burlington Northern Santa Fe and Union Pacific. Kansas City Southern is the other Class 1 railway in the United States, with a network stretching from the Midwest to the US Gulf Coast (USGC) and farther south into Mexico.

As common carriers, railways have an obligation to respond to all reasonable requests for transport. This obligation provides few rights of refusal, and railroads assume the liability associated with the transport of goods regardless of the risks. In this way, rail must permit the transport of hazardous materials like chlorine—essential for sanitation and clean drinking water—that otherwise may be unable to reach market at a reasonable cost.

Tank cars

A tank car is a specialized freight car designed for carrying liquids or compressed gases. Tank cars can carry nonhazardous and hazardous goods.⁶ Crude and ethanol are considered “hazardous materials” in the United States and “dangerous goods” in Canada.

Figure 1



5. A freight railway operating in Canada is considered Class 1 if it has operating revenues exceeding \$250 million. The United States uses the same threshold but adjusts it for inflation every year. For example in 2012, Class 1 railways were those that had revenues in excess of \$452.7 million. Source: Canada Transportation Act., Part II Rail Carriers, <http://laws-lois.justice.gc.ca/eng/acts/C-10.4/> -- accessed 29 August 2014. Surface Transportation Board, <http://www.stb.dot.gov/stb/faqs.html#econ>, accessed 29 August 2014.

6. Corn syrup and vegetable oil are examples of nonhazardous goods.

Various tank car designs that differ by their features and intended service are permitted by regulators. These requirements establish a minimum threshold for cars transporting dangerous goods. The design and durability of key features, such as the type and thickness of shell steel, affect the crashworthiness of a tank car and are a source of differences between cars.

The most common tank car specification in North America is the US Department of Transportation 111 (DOT-111). These general purpose tank cars are designed to carry both nonhazardous and hazardous liquids. According to the Railway Supply Institute (RSI), which represents railcar manufacturers, at midyear 2014 DOT-111 cars accounted for 80% of all tank cars in service in North America (about 270,000 out of 330,000 cars).

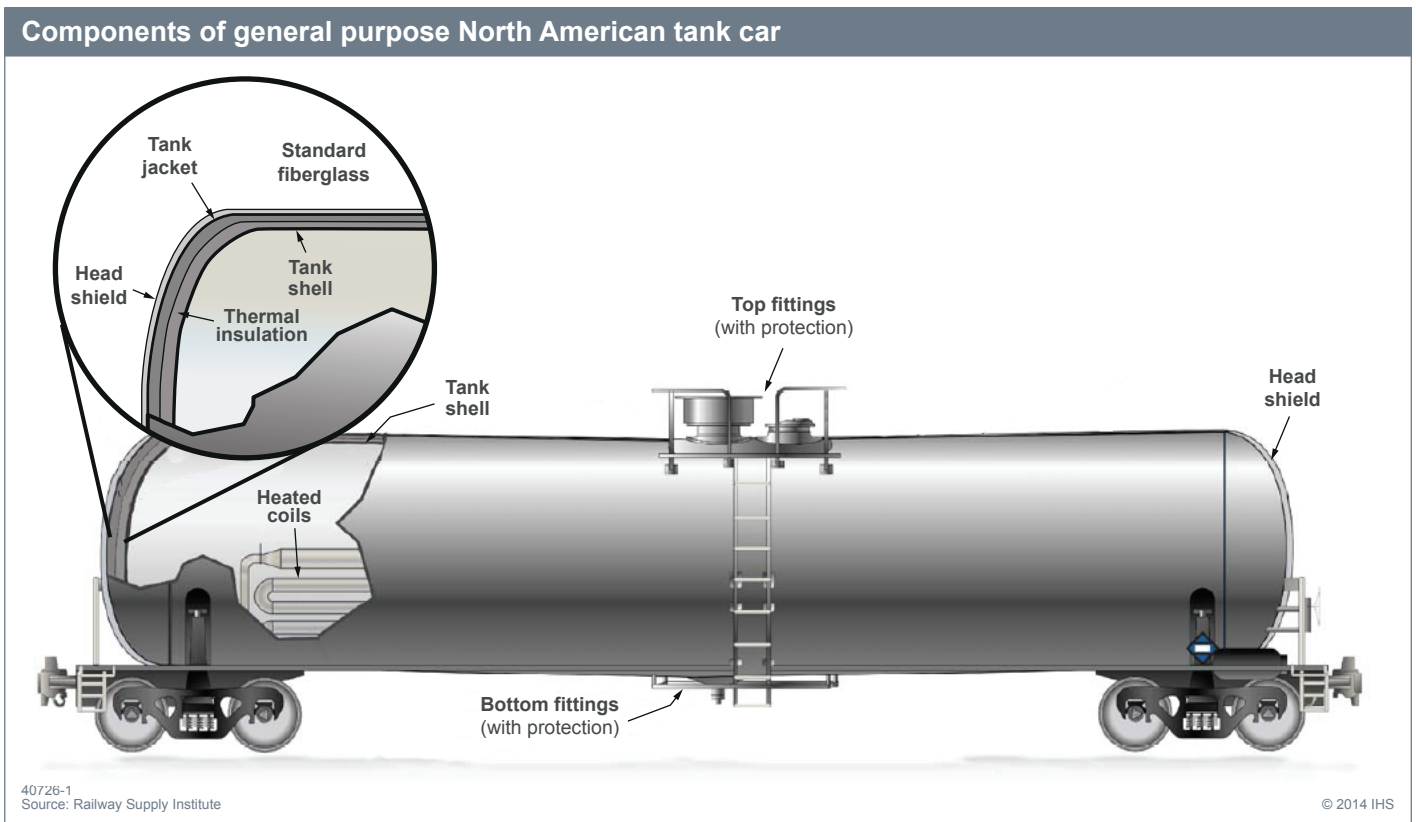
Weight and volume limits: Reaching one before the other

Tank cars are both weight and volume restricted. For a given tank car, liquids of different densities can reach one limit before the other. Therefore, tank cars are often purpose-built to the size and weight for the commodity they will handle and directed into dedicated service. For example, a light crude oil, such as tight oil, is most likely to be volume restricted before weight limits are reached. However, the reverse is true for a heavy crude oil, such as oil sands bitumen blends.

Below is a description, including a depiction shown in Figure 2, of features common to all tank cars, followed by some that have been historically optional. Common features include

- **Tank.** A tank is made up of a shell (the long cylindrical part) with two hemispherical heads (the ends of the tank). Depending on the density of the commodity carried, the capacity of a DOT-111 tank can range from about 10,000 to 34,500 gallons (maximum capacity is around 30,000 gallons for crude oil).
- **Fittings.** Fittings include the equipment that enables the contents to be loaded and unloaded and that can relieve pressure in the event of unplanned pressure buildup while in transit or due to exposure to fire. There are fittings on top

Figure 2



of the shell (“top fittings”), which can be enclosed within a protective housing (a requirement for newer DOT-111 cars). Some cars may also have bottom fittings.

- **Stub sills and couplers.** Stubsills are located on either end of the tank and support the structure. They absorb the forces a railcar is subject to as the train moves along the track. Stubsills are equipped with couplers that connect the tank cars to other cars in the train.

Optional features include

- **Head shields (partial or full).** A tank car may have a partial or full head shield, which deflects or absorbs an impact that otherwise could puncture the head of a tank car.
- **Thermal protection.** In the event of a fire, thermal protection prevents a rapid rise in temperature in the car, which could cause this pressure to build faster than can be vented, compromising the tank car or resulting in an explosion.
- **Jacket.** Jackets (with or without insulation) act as a double hull, absorbing energy in the event of an accident and preventing an unintended release of the cargo.⁷

These optional features have been proposed as mandatory for certain future tank car designs discussed in Part 5 of this report.

Part 3: The history and outlook for crude by rail

The Great Revival underpins the rise of crude by rail

The growth of crude by rail is tied to the Great Revival of North American oil production. For decades, North American production had been trending down. Oil sands production began to increase significantly in the early 2000s, but overall North American output was in a long-lasting decline. Starting in 2009, this changed. North American production began to grow again—and rapidly. Rising output in the United States and Canada has backed out offshore imports, and North America is becoming increasingly self-reliant in meeting domestic oil demand. Since 2009, North American gross imports of offshore crude oil have fallen by 2.8 MMb/d, to 5 MMb/d in 2014. Production increased 4.4 MMb/d, to 12.4 MMb/d, making North America the largest source of world oil supply growth during this time. Moreover, Canada became by far the largest source of imported oil into the United States.

Historically, North American transportation infrastructure for crude oil was designed to move production and imports to inland markets from coastal regions. In some regions, the Great Revival has led to supply overtaking existing pipeline capacity. To get growing production to market, producers have turned to rail because of its relatively low capital cost and speed to build.⁸ In less than five years, crude by rail has increased from a modest 20,000 b/d (12,000 carloads) in 2009 to over 950,000 b/d (about 540,000 carloads) in 2013. By the end of 2014 annual average movements could exceed 1.1 MMb/d—nearly 9% of North American production. In some regions, however, the reliance on rail is much higher. In North Dakota, for example, rail accounts for about 68% of all crude transportation.⁹

Shipping crude oil has become an important part of North American railroad operations—not to mention crucial for US supply growth—delivering not only crude oil to market, but the goods required to support production, such as steel, pipe, and sand. Yet the movement of crude by rail still represented less than 3% of all rail movements by weight (fewer than 2% of all carloads) in 2013.¹⁰

7. Insulation helps maintain the temperature of the lading (i.e., cargo) in transit.

8. Compared to pipeline that can take several years to develop and bring online, with some pipelines being subject to additional regulatory delay, new rail loading capacity can be brought online in about one year. Source: Gibson Energy and USD completed a rail logistics facility at Hardisty, Alberta. The project was announced on 6 August 2013 and completed on 31 July 2014. See <http://usdg.com/media/press-releases>.

9. As of August 2014. Source: North Dakota Oil and Gas Division, <https://www.dmr.nd.gov/oilgas/stats/statisticsvw.asp>—accessed October 2014 and North Dakota Pipeline Authority, <http://northdakotapipelines.com/rail-transportation>, accessed October 2014.

10. Estimate based on revenue freight from the IHS Transearch North American freight flow database.

Uncertainty surrounds the outlook for crude-by-rail volumes in North America. Key areas of uncertainty include the timing of new pipeline capacity; the extent of crude production growth, particularly of tight oil; and regulatory factors. At present, IHS expects North American production growth to continue to outpace new pipeline capacity and the movement of crude by rail to continue to build, although a lower oil price environment could ease the growth of crude by rail.

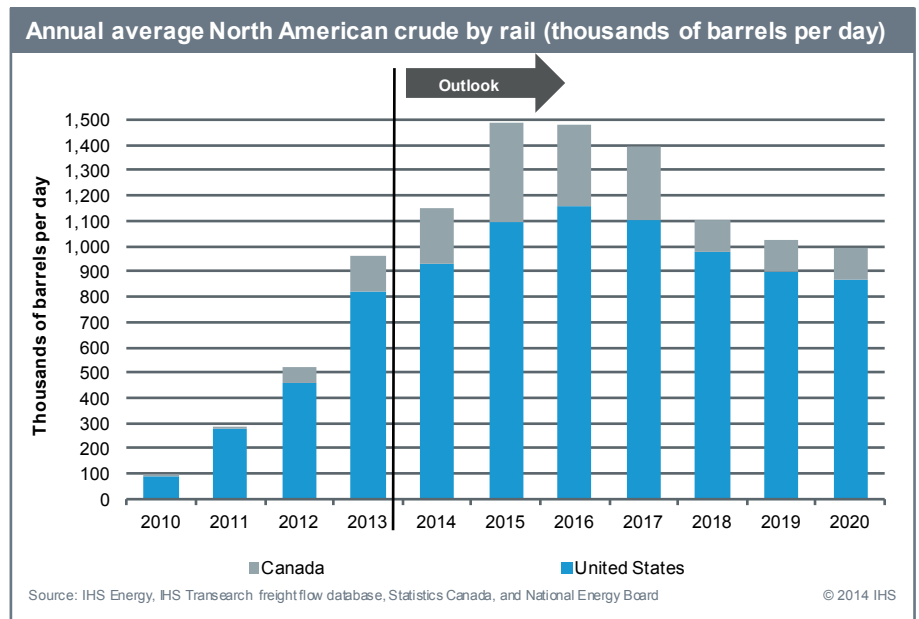
Pipeline capacity the key to the peaking of crude by rail

Several large proposed pipeline projects and expansions exiting western Canada and North Dakota could be online in 2016–18.¹¹ Since moving crude by pipeline is less expensive than moving it by rail, the addition of new pipeline capacity will contribute to the peaking of crude by rail movements between 2015 and 2016 at around 1.5 MMb/d, or over 10% of North American production (see Figure 3). However, should growth be greater than anticipated and/or pipeline projects encounter delays, crude-by-rail movements could peak at a higher level at a later date.

North Dakota tight oil growth: A key driver of crude by rail

Most crude-by-rail movements in North America have occurred in the United States. The majority of these movements have come from production growth in North Dakota. Between 2009 and 2013, Bakken production expanded nearly 500%—from 170,000 b/d to 850,000 b/d—and by the end of 2014 Bakken production is expected to exceed 1.1 MMb/d. With limited access to pipelines and major refining centers some distance away, much of this incremental growth has ended up on the rails. By August 2014, crude by rail departing North Dakota averaged around 765,000 b/d.¹²

Figure 3



In 2013, just over two-thirds of all North American (or over three-quarters of all US) crude-by-rail movements came from North Dakota. Over half of all movements terminated in the USGC. Fewer movements occurred throughout the United States, with the only other notable source of crude by rail in the lower 48 states coming from growing tight oil production in Texas.¹³

US rail movements are expected to continue to rise largely as a result of growing North Dakota production. However, the destination is shifting from the USGC and toward the East, West, and even the US Midwest. USGC refiners are near the limit of their ability to consume greater quantities of light, sweet crude. Growing production from the Eagle Ford in South Texas and the Permian Basin in West Texas is displacing more distant production from North Dakota. The East Coast market of Canada and the United States is a particularly good fit for North Dakota production. A number of refineries on the East Coast designed to import and run offshore light crudes are not connected to pipelines. In 2014, IHS estimates that these refineries collectively consumed about 1.3 MMb/d of light, sweet crude oil, making them a natural fit for Bakken crude.

11. These include, pending approval where appropriate, expansion of the Canadian mainline, Energy East, Keystone XL, Pony Express Sandpiper, and Trans Mountain Expansion. Northern Gateway obtained regulatory approval in 2014 but has been postponed by Enbridge, anticipated by IHS in 2019.

12. North Dakota Pipeline Authority, Estimated North Dakota Rail Export Volumes, <https://ndpipelines.files.wordpress.com/2012/04/nd-rail-estimate-april-2014.jpg>, accessed 31 October 2014.

13. Source: IHS Transearch database.

The trajectory of all US crude-by-rail volumes is difficult to predict because inland transportation of crude oil is becoming increasingly complex. Pipeline, rail, barge, and marine tankers will all be leveraged. There is additional uncertainty from the continuing ban on US crude oil exports that could exacerbate imbalances between refinery demand and domestic supply.¹⁴

IHS currently expects crude-by-rail movements originating in the US to peak between 2015 to 2017, with volumes hovering around 1.1 MMb/d before beginning to subside in 2018 (see Figure 3).¹⁵ This plateau is linked to a combination of planned new pipeline capacity, such as Sandpiper, Pony Express, Keystone XL, Line 9 reversal, and Energy East; completion of new refining capacity in and around North Dakota; and moderation in the pace of production growth. Should production be higher or pipeline projects be delayed, volumes shipped by rail would be higher.

Western Canada: Crude by rail is just beginning

Production from western Canada is finding its way onto the rails, although the volume is modest compared with the United States. A combination of supply growth and delays in the addition of new pipeline capacity is behind this trend. Western Canadian production, led by the oil sands, has been rising steadily for a number of years. Most existing western Canadian pipeline takeaway capacity transits to the US Midwest. Some of the western Canadian pipeline takeaway capacity is also accessible to North Dakota via cross-border “on-ramps.” Combined tight oil and western Canadian supply growth has led to bottlenecks at various stages of the pipeline transportation system. As a result of growing supply and insufficient pipeline takeaway, the price of western Canadian oil has been discounted, sometimes quite severely. For example, Cold Lake Blend, a western Canadian heavy crude oil benchmark, historically traded at a discount of around \$20 per barrel (bbl) compared with Brent, a globally traded light crude oil benchmark.¹⁶ But since 2011, the Cold Lake Blend has traded at a discount of about \$30/bbl, and at times by as much as \$60/bbl compared with Brent.¹⁷ These discounts and the lack of incremental capacity on existing pipelines prompted some producers to turn to rail. As shown in Figure 3, crude-by-rail movements from western Canada are expected to average around 220,000 b/d in 2014—up 80,000 b/d from 2013.

Most Canadian crude that moves by rail is heavy, unlike in the United States where it is mostly light. The largest market for heavy crude oil in North America, by far, is in the USGC region. IHS estimates that the market for Canadian heavy crude oil in the USGC could be up to 1.8 MMb/d.¹⁸ However, as production expands, rail may also provide inland western Canadian production access to offshore markets. For example, in September 2014, nearly three-quarters of a million barrels of western Canadian crude oil were exported to Italy after having been delivered by rail to a port near Montréal, Québec.¹⁹

Similar to the situation for US crude, movements of Canadian crude by rail could peak in a few years. After averaging about 400,000 b/d in 2015—nearly double the 2014 average—volumes of Canadian crude shipped by rail are linked to timing of new pipeline capacity. Should pipeline proceed as currently proposed, western Canadian movements are anticipated to begin to soften in 2016.²⁰ Should pipeline projects be delayed, the peak of Canadian crude-by-rail shipments would occur later and at a higher level.

A look at crude by rail economics: Crude by rail is here to stay

The Great Revival of crude production in North America is expected to provide opportunities for crude to move by rail for many years to come. As shown in Figure 3, even after significant new pipeline capacity comes online, meaningful movements of crude by rail will persist. This section discusses the economics and drivers of the future of crude by rail.

14. See the IHS Special Report *US Crude Oil Export Decision: Assessing the impact of the export ban and free trade on the US economy*.

15. A peaking of US crude-by-rail movements is visible in Figure 3. However this was deemed to be within the range of error with estimated movements in 2015 and 2017.

16. Estimated based on average monthly price Cold Lake Blend at Edmonton, Alberta, and Dated Brent, FOB between 2006 and 2010.

17. Estimate based on average monthly price from 2011 to October 2014.

18. See the IHS Special Report *Future Markets for Oil Sands*.

19. Source: Bloomberg, <http://www.bloomberg.com/news/2014-09-24/suncor-looks-east-to-find-buyers-for-western-canada-crude.html>, accessed 29 October 2014.

20. Specifically between 2016 to 2018, expansion of the Canadian mainline, Keystone XL, Trans Mountain Expansion, and Energy East are planned to be online.

Rail economics

Although rail provides producers the flexibility to alter markets from day to day to achieve a higher price for their output, cost and reliability continue to provide pipeline with an economic advantage over rail. Given the option, producers would generally prefer to ship their crude by pipeline. For example, on average it is estimated that rail costs about \$8 more to move a barrel of heavy crude blend from western Canada to the USGC compared with pipelines (see Table 1). In addition to a lower cost, the operation of pipelines—unlike railroads—is rarely impeded by weather and other external factors. For example, the estimated average travel time by rail from western Canada to the USGC and back (known as a cycle time) is about 16 to 20 days, but can be up to 30 days.²¹ Pipeline transport, for comparison, would average about 23 days (one way) with little variability.²²

To be sure, the revival of shipping crude by rail is still in the early days. Even over the past few years, the transport of crude by rail has become more efficient. Compared with early 2013, some costs associated with moving crude by rail—including transit times, gathering, and loading—have declined.²³ Use of unit trains over manifest is also leading to lower costs.²⁴ A unit train can carry more crude and deliver it more rapidly, with less handling (starts, stops, and switching of cars) than a manifest train. Unit trains provide more rapid transit and lower rates from reduced handling. Yet, point-to-point, as shown in Table 1, pipeline continues to have an advantage over rail in terms of cost.

As shown in Table 1, the costs of shipping crude by rail include loading and unloading tank cars at rail terminals; leasing or financing tank cars; and charges for transport by the railroad. The IHS estimate of the most likely average value has been provided for each component of transport; however, each input is subject to variability. The most likely range has been provided in the total column; however, in reality the range can exceed what has been shown. For example, if crude by rail requires gathering and transport by truck to rail terminal, loading costs can be as high as \$7/bbl. In addition to gathering costs, other factors can affect transport cost. Whether a train is unit or manifest affects the rate charged by railroad; tank car capacity, density of crude oil, and cycle times (round trip) all influence the per-barrel tank car lease/finance estimate. The density of the crude oil can impact terminal loading and unloading handling fees. For these reasons the economics of crude by rail for light, tight oil and heavy oil sands exist over a range and differ.

The future of rail is going where pipelines do not or cannot go

The ability of railroads to connect producers with remote refiners or to go more readily where pipeline may be challenged to reach will make rail a permanent feature of delivering inland crude (heavy and light) to refiners in North America.

21. Cycle time are impacted by a number of factors, including precise origin and destination, route, seasonality, weather, congestion, and whether train is manifest or unit train.

22. Assumes the completion of Keystone XL, anticipated to be the most direct route to the USGC with crude oil traveling at 5 kilometers per hour over 2,750 kilometers of pipeline.

23. See the IHS Energy Special Report *Keystone XL Pipeline: No material impact on US GHG emissions*.

24. A manifest train transports a variety of cargoes and makes multiple stops to deliver its goods. A unit train is a dedicated nonstop train of one commodity that takes a good from origin to destination and typically consists of 100 to 120 tank cars. Depending on the number of cars, tank car capacity, and density of crude oil, a unit train can transport between 60,000 and 80,000 barrels of crude oil.

Table 1

		Estimated average transportation cost for rail and pipeline from and to selected markets					
		Gathering/ loading	Lease*	Unloading	Transport	Total	
Pipeline	Bakken light crude oil to USGC	--	--	--	10.00	9.50 (+/- 1.00)	
	Western Canada heavy to USGC	--	--	--	10.50	10.50 (+/- 1.00)	
Rail	Western Canada heavy to USGC	1.50	1.50	1.50	14.00	18.50 (+/- 2.50)	
	Bakken light crude oil to East Coast	1.30	1.10	1.30	11.00	14.75 (+/- 1.5)	
	Bakken light crude oil to USGC	1.30	0.90	1.30	9.50	13.00 (+/- 1.5)	

Note: In US dollars. Transportation costs estimated in 2014. All estimates are average values rounded to the nearest decimal point. A most likely range has been provided in the "Total" column; however, considerable variability in crude by rail exists and in some instances cost can exceed even this range. For example at times, and under the right terms and conditions, the rate from western Canada to the USGC can approach \$26. Key factors that can affect variability include the rate charged by railroads, tank car capacity, density of crude oil being transported, tank car lease or financing rate, and cycle times (round trip). Tank car lease rates assumed to be \$1,500 per month. Estimated average cycle time (round trip) assumed above were 18 days from western Canada to the USGC; 15 days from North Dakota to the US East Coast; and 12 days from North Dakota to USGC. Tank car capacity based on weighted average of existing tank car fleet of 67% DOT-111 and 33% CPC-1232. Tank capacity estimates are 650 barrels for light crude oil, 600 barrels for heavy (dilbit). Additional tank car weight and terminal handling cost was assumed for dilbit transport, as it would likely require special heating capabilities for both railcars and terminals.

Source: IHS Energy

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A number of refineries in North America built near the coast to access offshore supplies have limited or no access to pipelines. Rail offers these facilities access to growing inland supply, which is expected to continue to be less expensive than offshore imports. A major concentration of facilities that are capable of processing heavy oil sands crudes is located in the USGC region, but additional opportunities may exist for heavy barrels across North America.²⁵ For light crude oil from North Dakota, the East Coast may provide longer-term opportunities for rail. It could also be particularly challenging to complete new pipelines to connect oil fields in the US Mid-Continent to refiners on the East Coast because the routes would likely need to pass through some of the most densely populated regions in the United States. This provides another longer-term opportunity for rail to transport crude.²⁶

There are unique opportunities to improve the economics of oil sands transport by rail

There are unique opportunities in the Canadian oil sands to improve the cost of transport by rail. Heavy crude from the oil sands is expected to continue to be the largest source of production growth in Canada, and therefore the largest source of crude transported by rail. Rail's ability to move raw bitumen (a pure bitumen-only barrel) from Canada's oil sands is cost advantaged over moving bitumen blends by rail.

The typical oil sands product shipped today is diluted bitumen, or dilbit. Diluent is added to bitumen to allow pipeline transport. Rail has no need for diluent and is capable of moving bitumen-only barrels—the raw undiluted oil sands product. Reduction of diluent can improve the cost of transport via crude by rail for heavy oil sands producers in two ways.

- **Diluent savings.** From a producers' perspective, diluents add cost to shipping bitumen. In fact, condensate, the most common form of diluent, is a premium priced crude oil in Alberta because of demand for bitumen blending. From 2012 to mid-2014, its price has been 25% higher than a barrel of Cold Lake Blend.
- **Transport savings.** Dilbit typically contains about 30% diluent. A reduction in the diluent increases the volume of bitumen that can be shipped and therefore saves capacity in transport.

Limited quantities of conventional heavy oil and pure bitumen from cold flow oil sands production are already being shipped.²⁷ Production from these facilities does not require the addition of diluent in production and can be moved provided it is warm.

Raw bitumen is not always readily available to ship by rail. Most of the diluent found in the typical dilbit is the result of the extraction process. During extraction, diluent is added to aid in the separation of oil and water and to enhance mobility. Following extraction, more diluent is added to further enhance mobility so as to meet pipeline requirements. Rail transport does not require the additional diluent and can ship the lower diluent blend. This is known as railbit and contains 12–18% diluent per barrel, compared with the typical pipeline dilbit with about 30% diluent.

Removing additional diluent to below production levels requires specialized equipment called a diluent recovery unit (DRU). A DRU can produce a near bitumen-only product, which has become known as neatbit. Neatbit contains about 1–2% diluent. The current cost to operate a DRU is estimated to be about \$1/bbl.²⁸ Some oil sands producers have announced their intention to build DRUs to support their bitumen-by-rail operation.²⁹ The full cost of moving a barrel of bitumen (i.e., 42 gallons of bitumen) plus the cost of purchasing and transporting the diluent is shown in Table 2. Even

25. Various blends of bitumen can provide opportunities for oil sands across North American.

26. To access eastern refiners, inland crude oil from North Dakota could be transported by pipeline to the USGC region and loaded on marine tanker for transit to refiners along the East Coast. IHS estimates this could be within the same cost range as by rail directly to eastern refiners. However, direct rail involves less handling and therefore less potential complications. Some quantities of crude oil from western Canada and North Dakota are also expected to be able to access eastern markets in Canada and the United States via the Energy East pipeline project and marine tanker at a lower cost than rail.

27. In some parts of the oil sands region, bitumen is less viscous and is extracted without steam.

28. Costs of operating a DRU are influenced by the price of the natural gas used to produce the heat required in the separation of the diluent and bitumen.

29. See MEG Energy 2014 Capital Budget and Guidance, www.megenergy.com/news-room/article/meg-energy-announces-2014-capital-budget-and-guidance, accessed 5 October 2014. See: *Financial Post*, "Cenovus looks to boost oil-by-rail economics," http://business.financialpost.com/2014/02/13/cenovus-looks-to-boost-oil-by-rail-economics/?__lsa=f6cc-6cc3, accessed 5 October 2014.

with the added cost of using a DRU, the cost of rail transport of neatbit is more competitive with pipeline than either dilbit or railbit.

Although pipelines remain cost advantaged, under certain conditions, i.e. a high pipeline cost and low rail cost scenario, the rail transport cost of neatbit could overlap the pipeline transport cost of dilbit. This scenario would require lower railroad rates than the estimates presented in Table 2. A full assessment of relative transportation economics would consider other factors. The price refiners would be willing to pay for the different crude blends is influenced by the marketable products refiners can produce from a given barrel of crude oil. Further, not all refineries may have the necessary configuration or front end infrastructure to handle neatbit and may need to make additional capital investments to run neatbit. In the absence of this refinery investment, the market for neatbit may be smaller than what may be achieved with higher diluent blends. Both of these factors could offset some of the rail transportation savings of neatbit.

Table 2

Average transport cost per full bitumen-only barrel (42 gallons of bitumen) plus additional diluent (from western Canada to the USGC)

	Pipe	Rail		
		Dilbit (30% diluent)	Railbit (15% diluent)	Neatbit (1.5% diluent) ^a
Average transport cost per barrel ¹	10.50	18.50	18.60	18.80
Cost to transport diluent ²	3.10	5.60	2.80	0.30
Cost to acquire diluent ³	2.40	2.40	1.20	0.10
Other cost (i.e., diluent recovery)				1.00
Effective cost	16.00 (+/- 1.25)	26.50 (+/- 3.25)	22.60 (+/- 3.00)	20.25 (+/- 2.50)

Note: In US dollars. Transportation costs estimated in 2014. All estimates are average values rounded to the nearest decimal point. A most likely range has been provided in the "Effective cost" row; however, considerable variability in crude by rail exists and in some instances cost can be higher than depicted. Refinery valuation of the different blends was not included, nor were potential commercial issues that could impact a producer's decision to pursue these alternative delivery options for bitumen production.

1. Average transport cost drawn from Table 1. For rail transport of railbit and neatbit, additional handling cost was assumed for terminal loading and unloading, and greater density would also impact the per-barrel tank car lease rate.

2. Value of diluent share of transportation space.

3. A simplifying assumption was made that the diluent cost is the arbitrage or difference price between Alberta and the USGC for condensate. Based on 2014 condensate prices by September 2014 this was estimated to be valued around \$8.

4. Costs shown for neatbit include only operating costs for diluent and transportation and exclude any capital recovery for DRU facilities. Some heavy oil sands barrels may not require DRU and may reach the loading terminal neat. Assumes neatbit barrel using DRU would contain 1.5% diluent.

Source: IHS Energy

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Part 4: Safety of moving crude oil by rail

Several high-profile accidents have accompanied the growth of crude by rail leading to question about whether this increased transport of crude oil poses greater risk.

This section addresses safety aspects of crude by rail, including which regulatory agencies are involved in overseeing the freight rail safety in North America? How have the frequency of accidents and safety in general changed over time and why? What is the history of hazardous material transport by rail? Do certain crude oils have greater volatility?³⁰

Regulating rail in Canada and the United States

In the United States and Canada, oversight of freight rail is under the jurisdiction of the federal government.³¹ Although Canada and the United States regulate freight rail independently, cross-border trade has resulted in symmetry of railroad regulations and operations.

The key federal regulatory agencies involved in freight rail safety in Canada and the United States are

- **Transport Canada.** Transport Canada is responsible for overseeing all railroads crossing provincial and international boundaries in Canada. It has authority over rail operations, track safety, traffic signals, and train control. Transport Canada also regulates the transportation of dangerous goods (i.e., hazardous materials). This includes the proper containment, packaging, placarding, and emergency response requirements.
- **The Department of Transportation (US DOT).** The US DOT is responsible for freight rail operations, including safety and transportation of hazardous materials in the United States. Its responsibilities in this area are divided between two key independent agencies:

30. Volatility refers to how easily a liquid evaporates. Flammable liquids are more combustible in a gaseous state.

31. In Canada, provinces can become involved if a railway operates solely within the confines of one province.

- **Federal Railroad Administration (FRA).** The FRA is principal regulator of freight rail in the United States. It is responsible for overseeing rail operations, track safety, signal and train control, and rolling stock and for enforcing hazardous material regulations.
- **Pipeline and Hazardous Material Safety Administration (PHMSA).** PHMSA has responsibilities for ensuring the safe transport of hazardous materials in the United States. This includes rail.
- **Transportation Safety Boards.** The US National Transportation Safety Board and the Transportation Safety Board (TSB) of Canada are independent transportation accident investigators. Their mandate is to investigate accidents of high public interest and to make recommendations to improve transportation safety. They have no regulatory power.

Other agencies and regulators are also involved in the safe movement of crude by rail in North America. For example, the US Department of Homeland Security is involved in safe route determination and identification of high-risk areas.

Deregulation transformed the railroad industry and safety

Economic deregulation early in the 1980s renewed investment in rail infrastructure and technology, which increased efficiency, productivity, and safety.³² Investments led to improvements in track maintenance and equipment, earlier detection of track and equipment issues, and better management of rail operations.

Examples of safety improvements include

- **Equipment.** Stronger, more durable parts and better design have reduced the wear and tear on equipment and lowered failure rates. Freight cars have also been improved. Wheels are now stronger and can bear greater weight. This, in turn, has reduced the number of cars required to move the same volume of goods, lowering the overall wear on rail equipment and infrastructure. More damage-resistant wheels have contributed to lower wheel failures. Locomotives have also benefited from advancements such as dynamic braking. By utilizing the engine as a resistor, friction and wear is reduced on braking systems.
- **Track.** Technology has been deployed on and along tracks for earlier detection of certain track and train equipment defects. Wayside detectors, placed at regular intervals along the track, have become more widespread to identify potential wheel problems. The proliferation of advanced track geometry cars has enhanced early detection of issues related to wear and track design that can impact car and train stability.
- **Rail operations.** Changes to operating procedures have also improved safety. Railways have improved training for operators and introduced antifatigue policies. Also, railways have adopted a systematic approach to risk reduction through safety management systems. By strategically placing engines throughout longer trains (known as distributed power), the wear on wheel, rails, ties, and track ballast have been reduced.

Crude oil is a hazardous material

Crude oil is categorized as a hazardous material in the United States and a dangerous good in Canada. Hazardous materials are a solid, liquid, or gas that can pose a threat to life and the environment. Gasoline, ethanol, fertilizer, chlorine, hydrochloric acid, and ammonia hydroxide are examples of other hazardous materials.

There are nine hazard classes, each requiring specific containment, known as packing procedures, and labeling.³³ Crude oil is generally considered a flammable liquid, a Class 3 material. This class is divided into three “packing groups”: Packing Group I (most dangerous), Packing Group II (moderate danger), and Packing Group III (least dangerous). These

32. The Staggers Rail Act in 1980 deregulated large aspects of US railroads by allowing them to set their own rates. In Canada, deregulation gradually occurred from the late 1960s through to the 1980s. One milestone in Canadian deregulation was in 1983, when the Western Grain Transportation Act allowed regulated rates to rise.

33. The nine hazard classes are Class 1: Explosive; Class 2: Gases; Class 3: Flammable liquid; Class 4: Flammable solid; Class 5: Oxidizing agents and organic peroxides; Class 6: Toxic and infectious substances; Class 7: Radioactive; Class 8: Corrosives; Class 9: Miscellaneous.

divisions take into account the flash point and initial boiling point of flammable liquids, such as crude.³⁴ Most crude oil and ethanol fit into Packing Group II. However, some have argued that given the severity of some accidents that have involved Bakken crude, it should be considered high hazard (Packing Group I). For more information on the factors involved in crude oil volatility, see the text box “Crude oil volatility.”

Regulators require cargoes to be tested and labeled with placards to identify the contents. Placards ensure that first responders follow the correct protocol in the event of an accident. PHMSA has proposed a new sampling and testing program for crude oil that will include information about the testing frequency, methods used, and assurance measures. Similar proposals have been made in Canada.

Crude oil volatility

To date, all the train accidents in which crude oil has ignited and/or exploded have involved light, sweet Bakken crude oil from North Dakota. This has led to public concerns that Bakken crudes could be more volatile than other crudes.

Like all crude oil, Bakken crude is a mixture of hydrocarbons, including liquefied petroleum gases such as propane and butane, which are more volatile than the heavier components of crude. Oil-producing regions usually have infrastructure that separates lighter hydrocarbons from the heavier ones, typically to meet pipeline specifications. These processes have been less common in the rapidly growing Bakken region than elsewhere, since this equipment is typically associated with pipeline infrastructure (for gathering both gas and liquids, which is less prevalent in the Bakken region). There is a concern that the presence of these lighter hydrocarbons may make Bakken crude relatively more combustible than other crude oils, and the North Dakota Oil and Gas Division is continuing to study this issue. In 2014, studies conducted by both the North Dakota Petroleum Council and PHMSA found Bakken crude oil to be similar in properties to other light crude oils.* ** PHMSA concluded that Bakken crude oil should all be treated as a medium- to high-risk flammable liquid, requiring a minimum of Packing Group I or II. However, North Dakota is continuing to study this issue and recently proposed new rules to require the separation of gases from liquids to help address safety concerns associated with the lighter hydrocarbons in Bakken crude.***

Oil sands crudes may have a lower flammable potential than other crudes. Currently, most oil sands crude production is being shipped as dilbit. Bitumen is very heavy and viscous. It has both a high flash point and a high boiling point. Diluent, typically a natural gas condensate, has both a low flash point and a low boiling point. Because of the diluent, dilbit typically fits into Packing Group II—medium hazard.**** However, the viscosity and flammability of neatbit (nearly pure bitumen) may be sufficiently low that it may not meet the classification as a flammable liquid.*****

*Source: PHMSA, “Operation Safe Deliver,” http://www.phmsa.dot.gov/pv_obj_cache/pv_obj_id_8A422ABDC16B72E5F166FE34048CCBFED3B0500/filename/07_23_14_Operation_Safe_Delivery_Report_final_clean.pdf, accessed 29 August 2014.

**Source: Turner Mason & Company for North Dakota Petroleum Council, “Bakken Crude Properties,” http://www.ndoil.org/image/cache/Bakken_Quality_Report.pdf, accessed 31 October 2014.

***See: North Dakota Industrial Commission, “Oil conditioning order: #25417,” <https://www.dmr.nd.gov/oilgas/Approved-or25417.pdf>, accessed 10 December 2014.

****Source: Cenovus, Specifications for Heavy oil/diluent mix, <http://www.cenovus.com/contractor/msds.html>, accessed 15 September 2015.

*****Source: Cenovus, Specifications for a bitumen emulsion, <http://www.cenovus.com/contractor/msds.html>, accessed 15 September 2015.

34. The Transportation of Dangerous Goods Regulations in Canada defines *flash point* as the lowest temperature at which the application of an ignition source causes the vapors of a liquid to ignite near the surface of the liquid or within a test vessel. The flash point can indicate the possible presence of highly volatile (i.e., easily evaporated) and flammable constituents in a relatively nonvolatile or nonflammable material. Source: Transportation Safety Board, 6 July 2014, Analysis of Crude Oil Samples, Montreal, Maine & Atlantic Railway, Train MMA-002, Section 2.2. The initial boiling point at a given pressure is defined as the temperature value when the first bubble of vapor is formed from the liquid mixture. For flammable liquids, defined as liquids with a flash point below 60°C, packing groups are defined as Packing Group I, initial boiling point of 35°C or less at an absolute pressure of 101.3 kilopascals (kPa) and any flash point; Packing Group II, initial boiling point greater than 35°C at an absolute pressure of 101.3 kPa and a flash point less than 23°C; and Packing Group III, if the criteria for inclusion in Packing Group I or II are not met.

Rail safety statistics in North America

Subtle differences exist between Canadian and US safety statistics

There are subtle differences between Canada and US rail safety statistics that can make direct comparisons difficult. For example, although an accident is generally defined as an event involving on-track equipment (such as locomotives, railcars, etc.), in the United States damage must exceed a specified threshold to be an accident. Crossings and other incidents, such as trespassing, are often reported separately in the United States. Of the approximately 11,539 accidents and incidents reported in the United States in 2013, only 1,813 were accidents, and the remaining 9,726 involved crossing or other incidents.³⁵ Where possible we have combined Canadian and US data. Where not possible we refer to US statistics, as it is a much larger market than Canada.³⁶

Train accidents have declined over past decade

From 2004 to 2013, train accidents in Canada and the United States fell 40%, from 4,462 to 2,660.³⁷ Freight rail accounted for nearly three quarters of these accidents, with the remainder involving passenger trains and railroad equipment.

Accidents on main tracks, which are more likely to be at higher speed and of greater consequence, were also down 40%, from 1,254 in 2004 to 748 in 2013. The most common type of train accident on main tracks is derailments. In 2013, derailments accounted for over 60% of accidents in Canada and the United States. Other accidents arise from collisions (involving another train or an obstruction along the track) and other events such as fire. Accidents can be caused by operational errors, including human error, or problems with equipment and track infrastructure. In 2013, the most common cause of an accident was human error, which accounted for about 40% of accidents.

Accidents involving the release of hazardous material have decreased

A statistical analysis of safety of crude by rail is difficult to undertake because only limited amounts of crude moved by rail prior to 2009. However, a relevant comparison can be made with accident rates involving hazardous materials. Hazardous material transport has increased in recent years, with 2.4 million carloads moved in 2013—about 8% of all carloads that year.³⁸

As shown in Figure 4, although the movement of hazardous materials by rail has nearly tripled since 1980, accidents have declined. For the last five years for which data are available, 2009 to 2013, there were one-third fewer accidents than in 1980–84. In 2013, 19 reported accidents involved a release in the United States, the lowest in recent history. On a North American basis, occurrences have remained fairly stable since 2008, with an average 25–26 events per year. Fatalities from accidents involving hazardous materials have occurred but are not common. According to the Association of American Railroads (AAR), the 47 fatalities from the Lac-Mégantic accident were nearly twice the 24 reported fatalities attributable to hazardous materials in transport by rail in the United States in 1980–2013.³⁹

Despite safety improvements by the railroads, there was very little crude oil that had been transported by rail prior to 2009. Between 2006 to early 2014, 13 accidents involving a release of crude oil or ethanol were reported in the United States. Five accidents involved the release of crude oil, which all occurred since 2013.⁴⁰ TSB reported five accidents with

35. FRA, Office of Safety Analysis, “Total accidents/incidents, Jan-Dec (2013 preliminary)”, <http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/summary.aspx>, accessed 23 November 2014.

36. Safety-related data is reported to the FRA in the United States and the TSB in Canada. Source: Transportation Safety Board of Canada, “Statistical Summary – Railway Occurrences 2013” and “Rail occurrence data review and follow-up (2014)”, <http://www.tsb.gc.ca/eng/stats/rail/index.asp>—accessed 31 October 2014. Source: FRA Office of Safety Analysis, <http://safetydata.fra.dot.gov/OfficeofSafety/Default.aspx>, accessed 23 November 2014.

37. Crossing and trespassing accidents have been removed from Canadian data for comparability purposes with US data.

38. Includes only movements within the continental United States.

39. US DOT, Pipeline and Hazardous Materials Safety Administration, Hazardous Materials Incident Database.

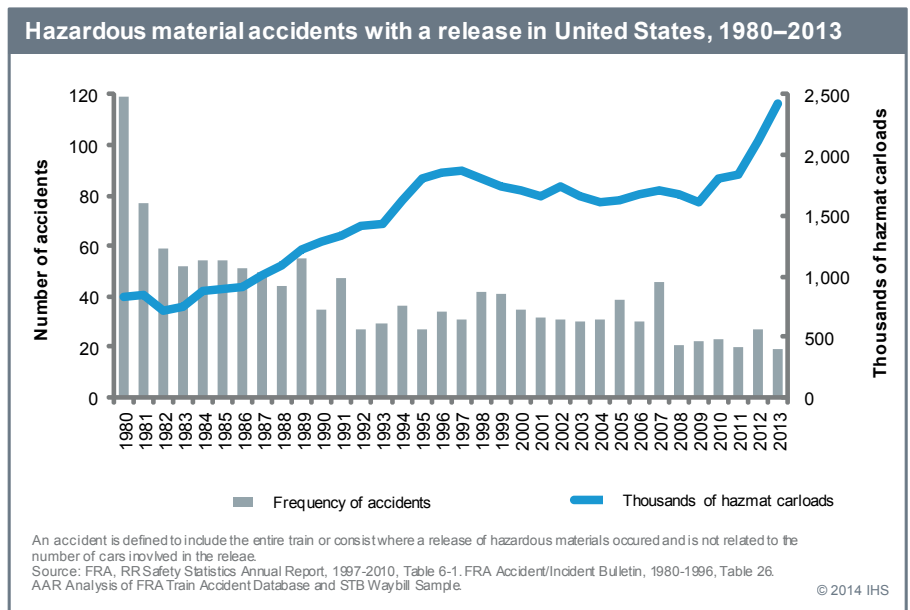
40. Source: See Federal Register, “Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains,” <https://www.federalregister.gov/articles/2014/08/01/2014-17764/hazardous-materials-enhanced-tank-car-standards-and-operational-controls-for-high-hazard-flammable>, accessed 28 November 2014.

a release in Canada in 2013.⁴¹ Given the expectation that movements will increase, new policies have been proposed that could lower the risk of accidents involving crude oil.

Part 5: Evolving policy

Efforts by industry and regulators to prevent and mitigate the impact of crude train accidents have intensified. Regulators are introducing new rules to reduce accidents involving crude (and ethanol) trains and to make tank cars more robust in the event of an accident. These measures are expected to lead to safer transport, but they may also contribute to increase transit times and reduce tank car capacity, both which could affect the capacity and cost of crude-by-rail transport. Ultimately the impact depends on the final rules enacted and the railroads' ability to increase efficiency. This section explores how areas of evolving rail policy could affect the movement of crude by rail in North America.

Figure 4



Speed restrictions lower risk, increase cycle time, and contribute to greater traffic

Regulators in Canada and the United States have proposed rules to reduce accidents involving crude (and ethanol) trains. In July 2014, the US DOT proposed rules aimed at preventing and mitigating the damage of accidents involving trains carrying large volumes of crude.⁴² These rules include those related to rail operations, such as speed limits, the use of routing analysis, and adoption of advanced braking systems. These rules impact trains consisting of at least 20 cars carrying crude, referred to as “key” crude trains.

- **Speed limits.** Generally, train speed are related to track quality, geometry (shape, curvature, etc.), and location (e.g., lower speeds in urban areas). Under the proposed new rules, key crude trains may be required to travel at 50 mph (or less). PHMSA is currently considering three options requiring slower speeds for trains that have at least one car carrying crude that is built to older DOT-111 specifications.⁴³ Trains using older tank cars may face speed limitations of 40 mph in all areas; in areas classified as “high threat urban areas” (HTUA); or in areas with a population of more than 100,000.⁴⁴
- **Routing analysis.** The operators of key crude trains are required to conduct an annual analysis of the routes that the train will travel in order to minimize safety and security risks. The analysis must take into account 27 factors, including the type of track and the population density and capability of emergency responders along the route.

41. TSB, “Statistical Summary – Railway Occurrences 2013,” <http://www.bst-tsb.gc.ca/eng/stats/rail/2013/ssro-2013.asp>,” accessed 28 November 2014.

42. See Federal Register, “Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains.” <https://www.federalregister.gov/articles/2014/08/01/2014-17764/hazardous-materials-enhanced-tank-car-standards-and-operational-controls-for-high-hazard-flammable>.

43. Tank car specifications are discussed in the next section.

44. The DOT considers a HTUA “an area comprising one or more cities and surrounding areas including a 10-mile buffer zone.”

- **Advanced braking systems.** Key crude trains are required to be equipped with one of three types of advanced braking systems (electronic controlled pneumatic brakes [ECP], a two-way end of train device [EOT], or distributed power [DP] locomotives).⁴⁵

Transport Canada has proposed rules in Canada that appear to be moving in a similar direction. In April 2014, Transport Canada ordered rail companies to formulate rules that, at a minimum, require that key trains carrying dangerous goods travel at less than 50 mph, and at less than 40 mph for trains that include at least one DOT-111 car carrying crude oil through areas identified as higher risk. In the same order, Transport Canada also directed rail companies to conduct an initial risk assessment of routes traversed by key trains carrying dangerous goods and to update the assessment periodically. The department also ordered wayside detectors that sense defective railcar equipment to be placed along major routes covered by key trains.⁴⁶

Before the US DOT and Transport Canada released the proposed rules described above, the rail industry committed to taking a number of steps in these areas and others to improve the safety of trains carrying crude. AAR members (which include both of Canada's two Class 1 railroads) committed to limit all key crude trains to 50 mph by July 2014 and those with at least one DOT-111 car or those traveling through a HTUA to 40 mph; conduct routing analysis for key crude trains; and ensure that all key crude trains traveling main tracks have either DP locomotives or EOT devices. AAR also pledged to perform at least one additional track inspection each year than is currently required by law and to install more wayside detectors.⁴⁷

Implications of stricter rail operational safety standards for oil industry

Regulators have not finalized the new rules aimed at increasing the operational safety of crude by rail. But it is quite likely that lower speed limits could prevail in at least some areas, particularly for trains operating with older style tank cars. Although speed limitations could reduce the likelihood and severity of derailments, it could also contribute to longer transit or cycle times. Over a fixed period, more trains and associated equipment such as locomotives, crews, and tank cars could be required to transport the same volume of crude. This may also impact railroad capacity, as valuable train equipment, such as locomotives and crews, may be required to support the increase in traffic. This could be exacerbated if other trains are delayed behind slower-moving crude trains.

Longer cycle times and more trains (and tank cars) could contribute to greater cost. Ultimately the extent of the impact depends on the final rule chosen, including a proposed new tank car standard, discussed below. The degree to which any cost impact could be moderated by further efficiencies in the transport of crude by rail is discussed in Part 3 of this report.

More robust tank cars are stronger, heavier, and have lower capacity

Regulators in Canada and the United States are proposing to phase out the older style tank car, known as the DOT-111 (this includes the most recent DOT-111 design known as CPC-1232 or TP14877 in Canada), and to require an enhanced standard for new tank cars built specifically to carry crude oil and ethanol, dubbed the DOT-117 (or TC-140 in Canada).⁴⁸

The older DOT-111 cars face an uncertain future. They may be scrapped, repurposed to other service, or modified to meet the new standard. As for their replacement, various designs for a new, purpose-built tank car have different costs and capacity and thus would impact tank car demand and availability in different ways. If a tank car shortage were to result,

45. These braking technologies or locomotive placements (DP) along the train assist in more rapid deceleration.

46. See Transport Canada, "Minister of Transport Order Pursuant to Section 19 of the Railway Safety Act." <http://www.tc.gc.ca/eng/mediaroom/ministerial-order-railway-7491.html>.

47. For additional actions taken by the AAR see www.aar.org/Fact%20Sheets/Safety/CBR%20One%20Year%20Later%20Fact%20Sheet.pdf.

48. See Federal Register, "Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains," <https://www.federalregister.gov/articles/2014/08/01/2014-17764/hazardous-materials-enhanced-tank-car-standards-and-operational-controls-for-high-hazard-flammable>; and Transport Canada, "Consultations on proposed amendments to the transportation of dangerous goods regulations," <http://www.tc.gc.ca/eng/tdg/clear-modifications-menu-261.htm>.

crude oil producers could have difficulty in moving their product to market and crude price discounts could result. An inability to deliver ethanol to market could affect the market for ethanol and, subsequently, retail gasoline prices.⁴⁹

The existing North American tank car fleet

The Canadian and US governments have announced plans to phase out 72,000 tank cars currently in crude and ethanol service.⁵⁰ There are two tank cars currently used in the transport of crude and ethanol in North America: the older style DOT-111 and the more recent DOT-111 design (the CPC-1232).

- **DOT-111—the workhorse of the North American tank car fleet.** DOT-111 cars are a nonpressure general-purpose tank car designed to carry liquids, both hazardous and nonhazardous. Because of its versatility, the DOT-111 has been the workhorse of the North American tank car fleet, accounting for four out of five tank cars (or 270,000 out of 330,000 tank cars).⁵¹ About one-fifth of the 270,000 DOT-111s are used to carry crude and ethanol (roughly half and half) (see Table 3). The DOT-111 comes in a range of sizes up to about 30,000 gallons and is weight restricted to 263,000 pounds (lbs) (inclusive of the weight of the car [known as tare weight]).

- **CPC-1232—a DOT-111 with several upgrades and greater weight capacity.** The CPC-1232 (TP14877 in Canada) is a newer design DOT-111 that has been built since November 2011. It comes in various sizes up to about 30,000 gallons and has a greater maximum load than the older style DOT-111, 286,000 lbs.⁵² For higher-density liquids, such as heavy crude oil, a greater weight capacity improves the economics of the tank car,

requiring fewer cars for a fixed quantity of goods. Also, the CPC-1232 has a number of safety improvements over older style DOT-111s, such as partial head shields, insulation, and top fitting protection.

Table 3

North American crude oil and ethanol tank car fleet, June 2014			
	Crude oil	Ethanol	Total
DOT-111	28,300	29,300	57,600
DOT-111 (jacketed)	5,500	100	5,600
DOT-111 (non-jacketed)	22,800	29,200	52,000
CPC-1232	14,250	480	14,730
CPC-1232 (jacketed) (7/16th)	4,850	0	4,850
CPC-1232 (non-jacketed) (1/2")	9,400	480	9,880
Total tank cars by service	42,550	29,780	72,330

Source: RSI, 14 June 2014

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The United States and Canada are currently pursuing separate phaseout schedules

Phase out of the existing tank car fleet, shown in Table 3, is expected to begin in 2017. The United States and Canada are currently pursuing separate phaseout schedules, shown in Figure 5. In Canada, the use of DOT-111 for crude and ethanol service must cease by May 2017, leaving just those cars built since November 2011 (the CPC-1232 and the DOT-117). The United States has proposed phasing out all DOT-111, including CPC-1232, for crude and ethanol service by packing group beginning in October 2017 for goods classified in Packing Group I (high hazard goods). The phaseout of Packing Group II, where most crude and ethanol fit, is expected in October 2018.

The transport of crude oil across the Canada-US border will be required to comply with the most stringent regulations (in other words, the earliest phaseout) of the two nations. As shown in Figure 5, this could equate to the phaseout of DOT-111 in May of 2017 in Canada, and then the phaseout of CPC-1232 in October 2018 in the United States (assuming Packing Group II). This could have implications for cross-border trade. However, Canada and the United States may yet harmonize their phaseout schedules.

49. Both the United States and Canada have renewable fuels standards that mandate a specified volume of ethanol in the gasoline.

50. Source: RSI, 14 June 2014.

51. Source: PHMSA/FRA, DOT, Notice of proposed rulemaking, "Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains," RIN 2137-AE91, July 2014.

52. Until 2011, freight cars were weight limited to 263,000 lbs. Advancements in stronger wheel assemblies led regulators to permit heavier tank cars. Under certain specifications the maximum permissible load increased from 263,000 lbs to 286,000 lbs in 2011. This contributed to the development of the CPC-1232 design. The CPC-1232 meets or exceeds DOT-111 standards and was sanctioned by the AAR in November 2011.

The phaseout of the existing crude and ethanol fleet is not without cost

The phaseout of older tank cars at a time when they are already in high demand to meet rising crude-by-rail transport may place even greater upward pressure on tank car prices. Following the phaseout dates, existing tank cars will either be scrapped, repurposed to another service (non-crude oil and ethanol service), or upgraded to the new standard. For shippers, the first two options are equivalent in the sense that they effectively remove the car from crude and ethanol service.

The timing of the phaseout, tank car manufacturing capacity, and the extent that existing cars can be modified will influence availability and tank car prices. Already over 72,000 tank cars in crude and ethanol service may need some degree of modification under the proposed rules (see Table 3). RSI has expressed concern that the schedule proposed by PHMSA earlier this year could result in a tank car shortage. In addition to the time it could take to clear backlogs or retool facilities to a new standard, RSI estimates that tank car manufacturing capacity may be capable of delivering about 20,000 new tank cars and modifying about 5,000 tank cars per year (depending on labor, shop availability, and the complexity of the modifications).⁵³ With tank car demand rising, and the initial stage of the phaseout in 2017, tank car supply could tighten, with cost implications for crude by rail.

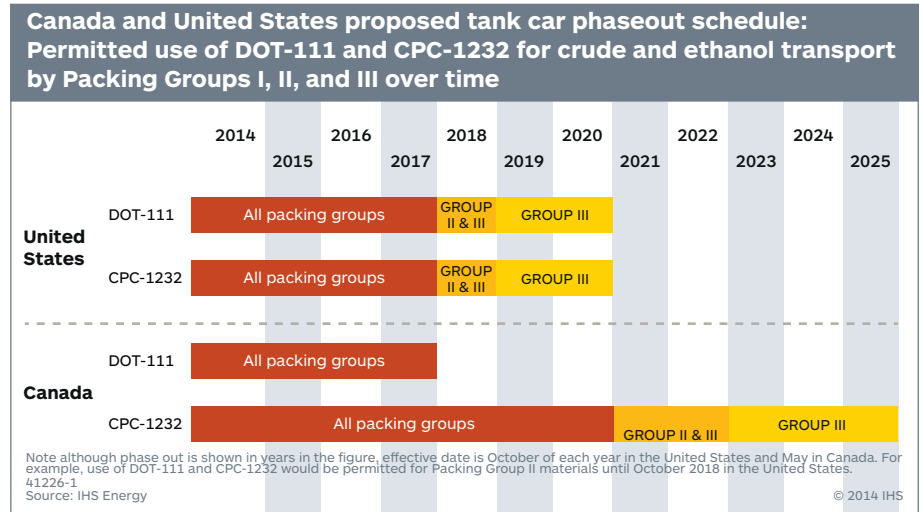
The more robust the tank car, the greater the impact on tank car demand

The US DOT announced on 23 July 2014 that it was seeking comments within 60 days on design proposals for the DOT-117. The DOT has proposed three options: the enhanced CPC-1232 (hereafter referred to as CPC-1232+), AAR 2014, and PHMSA/FRA 2014 (see Table 4).⁵⁴ The CPC-1232+ is essentially the jacketed CPC-1232 with enhanced top and bottom valve protection. The AAR 2014 and PHMSA/FRA build on the CPC-1232+ design with thicker shells (9/16-inch steel). PHMSA/FRA mirrors the AAR 2014 design with the addition of a stronger, rollover-resistant top fitting protection and Electrically Controlled Pneumatic (ECP) brakes. Transport Canada also proposed a new standard for a crude-carrying tank car, dubbed the TC-140. The TC-140 closely aligns with the PHMSA/FRA designed DOT-117, shown in Table 4.⁵⁵ Final decision on the future tank car standards is expected in early 2015.

While all three DOT-117 tank cars feature various safety enhancements over their predecessors, the increased resilience among the options being considered will mean greater tare weight and thus lower capacity. Compared with older style DOT-111 built prior to 2011, both the CPC-1232 and DOT-117 have a higher weight limit of 286,000 lbs (including the tare weight of the car), and thus greater capacity, as shown in Table 4. The phaseout of the lower-capacity older style DOT-111, which made up approximately 67% of the existing fleet in mid-2014, could reduce the number of cars required to move an equivalent volume of crude oil (see Table 3).

However, there are potential trade-offs among the various options being considered as the future crude and ethanol tank car. The key difference is the increase in weight between the steel requirements of the various standards. We estimate

Figure 5



53. Source: Railway Supply Institute, Committee on Tank Cars—Comments on PHMSA Proposed Rule: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains, www.regulations.gov/#:documentDetail;D=PHMSA-2012-0082-2279, accessed 13 November 2014.

54. US Department of Transport, Pipeline and Hazardous Material Safety Administration, Notice of Proposed Rule Making on Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable, July 23, 2014, Posted to Federal Registry, August 1, 2014 http://www.gpo.gov/fdsys/pkg/FR-2014-08-01/pdf/2014-17764.pdf.

55. Transport Canada, http://www.tc.gc.ca/eng/tdg/clear-modifications-menu-1193.html, 23 July 2014.

Table 4

Comparison of existing and proposed North American tank car standards for crude oil and ethanol rail transport										
Tank car specifications	Key differentiating features								Capacity in barrels	
	Head shield	Thermal protection	Jacketed	Shell thickness (inches)	Top-fitting protection	Rollover-resistant top fitting	Bottom outlet valve protection	ECP breaks	Bakken (API 40) ¹	Oil sands (API 22) ¹
DOT-111 (pre 2011)				7/16					675	580
CPC-1232 (post 2011)										
Jacketed	half	✓	✓	7/16	✓				710	630
Non-jacketed	half			1/2	✓				710	n/a
DOT-117 (proposed)										
CPC-1232+	full	✓	✓	7/16	✓		impact resistant		640	630
AAR 2014	full	✓	✓	9/16	✓		impact resistant		686	617
PHMSA/FRA 2014	full	✓	✓	9/16	✓	✓	impact resistant	✓	686	617

1. Tank car assumed to be 30,000 gallons with 1% outage for all standards used for Bakken crude oil and the DOT-111 for oil sands (dilbit). All other oil sands tank cars assumes 26,000 gallons with heated coils and insulation. Because insulation typically comes with a jacket, no value is provided for non-jacketed oil sands capacity.

Source: IHS Energy and Department of Transport, Pipeline and Hazardous Material Safety Administration, Notice of Proposed Rule Making on Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable, 23 July 2014, Posted to Federal Registry, 1 August 2014 <http://www.gpo.gov/fdsys/pkg/FR-2014-08-01/pdf/2014-17764.pdf>. © 2014 IHS

the difference between the 7/16-inch steel option and the 9/16-inch steel option to be about 16 bbl per car (for the difference between CPC-1232 and CPC-1232+, and the AAR 2014 and PHMSA/FRA options, see Table 4.) This is relatively minor yet could result in a greater number of carloads between them. For example, if all the crude in 2013 were moved in 9/16-inch cars instead of 7/16-inch cars, 15,000 additional carloads could have resulted—or 2.75% more. Thus, the heavier DOT-117 option could drive greater tank car demand, traffic, and cost than the lighter cars.

Implications of heavier, more robust tank cars for crude by rail

The phaseout of the existing tank car fleet has implications not only for the cost of crude by rail, but also for the availability of tank cars in North America. The pace of the phaseout and the standard chosen will affect the ability of tank car manufacturers and modification shops to meet demand. However, it is safe to assume the phaseout will not be without cost. From the perspective of the shippers (crude and ethanol producers), it is uncertain who will bear these costs (whether tank car owners, shippers or the railroads, or all three to various degrees), as well as does whether additional efficiencies, discussed in Part 3, could offset or even overcome any cost pressures.⁵⁶

56. Railroads could indirectly bear some of the cost by adjusting rates to maintain a desired level of movements.

Report participants and reviewers

IHS hosted a focus group meeting in Ottawa, Ontario, on 3 April 2014 to provide an opportunity for stakeholders to come together and discuss perspectives on the key issues related to the growing transport of crude by rail in North America. Additionally, a number of participants reviewed a draft version of this report. Participation in the focus group or review of the draft report does not reflect endorsement of the content of this report. IHS is exclusively responsible for the content of this report.

Alberta Department of Energy

Alberta Innovates—Energy and Environment Solutions

American Petroleum Institute

BP Canada

Canadian Association of Petroleum Producers

Canadian Natural Resources Limited

Canadian Oil Sands Limited

Cenovus Energy Inc.

ConocoPhillips Company

Imperial Oil Ltd.

In Situ Oil Sands Alliance (IOSA)

Natural Resources Canada

Railway Association of Canada

Shell Canada

Statoil Canada Ltd.

Suncor Energy Inc.

Total E&P Canada Ltd.

TransCanada Corporation

IHS team

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Malcolm Cairns Consulting

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