SAFETY FIRST

Intermodal Safety for Oil and Gas Transportation

Kenneth P. Green
Taylor Jackson

FRASER INSTITUTE
2017

Contents

Executive Summary

A contentious road lies ahead for the construction of three recently approved oil pipelines (Trans Mountain, Line 3, and Keystone XL). Given continued opposition to oil and gas infrastructure, we have examined the latest data on the safety of oil and gas transport. In general, the transport of oil and gas is quite safe by all modes we examine: pipeline, rail, and tanker, though there are differences between the modes that should be considered when developing infrastructure.

Pipelines suffer few occurrences (accidents and incidents) given the amount of oil and gas that is shipped through them. Overall, between 2004 and 2015, pipelines experienced approximately 0.05 occurrences per million barrels of oil equivalent (Mboe) transported.

When petroleum and natural gas goods are evaluated separately, we find that the transportation of oil results in fewer occurrences than the transport of natural gas. Indeed, transporting petroleum products by pipelines resulted in approximately 0.04 occurrences per Mboe compared to 0.07 for natural gas products. This means that the rate of occurrences for transporting natural gas products was 1.67 times greater than the rate of occurrences for petroleum products.

The focus on the occurrence rate only tells part of the story for pipeline safety. In addition to having low occurrence rates, almost 70 percent of pipeline occurrences result in spills of less than 1 cubic metre (17 percent result in no spill). Only 17 percent of pipeline occurrences take place in the actual line pipe, meaning that the vast majority of spills occur in facilities that often have secondary containment mechanisms and procedures.

The results were similar for rail, where the transportation of oil was found to result in fewer accidents per Mboe transported than natural gas. Also similar to the data on pipelines, most rail accidents occurred in facilities rather than in transit.

While both pipeline and rail transportation of oil and gas are quite safe, when comparing the two modes of transportation, pipelines continue to result in fewer accidents and fewer releases of product, when taking into consideration the amount of product moved.

Specifically, based on petroleum product transport data from 2004 to 2015, pipelines were 2.5 times less likely than rail to result in a release of product when transporting a million barrels of oil.

This study also evaluated marine tanker safety in light of the additional oil tankers that will result from the expansion of the Trans Mountain pipeline.

Since the mid-1990s there has not been a single major spill from oil tankers or other vessels in Canadian waters. One recent study conducted by the federal government on marine oil spill preparedness estimated that a major spill of over 10,000 tonnes was exceedingly rare and likely to only occur once every 242 years. Likewise, a spill of 100 to 1,000 tonnes is expected to occur once every 69.2 years.

Marine safety has also improved dramatically since the 1970s. For example, when comparing the number of spills in the 1970s to the 2010s (up to 2016) using international data, the number of spills between 7 and 700 tonnes has decreased from 543 to 35 and in this same period the number of large spills (>700 tonnes) has declined from 245 to 12. The amount of oil spilled has also dropped dramatically, falling from three million tonnes in the 1970s to only 39,000 tonnes in the 2010s.

In addition, compared to pipelines and rail, marine tanker transport is found to result in the fewest number of accidents per million barrels of oil transported.

Introduction

In November 2016, Prime Minister Justin Trudeau announced the approval of two new major oil export pipelines—the Trans Mountain pipeline expansion to British Columbia's coast and the replacement of Enbridge's Line 3, running from Hardisty, Alberta to Superior, Wisconsin in the United States. Then in March 2017, President Donald Trump announced that he was reversing the Obama administration's decision to block the Keystone XL pipeline by granting the cross border piece of energy infrastructure the presidential permit that it required. Keystone XL will transport oil from Hardisty, Alberta down to Steele City, Nebraska. When completed, these three pipelines will together add 1.79 million barrels per day of export capacity for Canadian oil.

But the pathway to construction will be arduous; all of these pipelines face opposition and a difficult and contentious process will face these projects until they are completed. While some of the opposition to the pipelines is centered on bigger debates about humanity's continued use of fossil fuels for energy, much of it also rests on the safety of the pipelines and the potential risks associated with them. Indeed, rhetoric surrounding the safety of pipelines can often border on hyperbole.

The purpose of this study is to review the data on the safety of pipelines for transporting oil and gas, and compare it with the safety record of transport by rail and marine tankers. The study's goal is to present a reasoned assessment of the risk of the various methods of oil and gas transportation to provide solid data useful in the debate that will be levied against the expansion of Canada's pipeline infrastructure.

This study builds upon previous research (see Furchtgott-Roth and Green, 2013; and Green and Jackson, 2015) by differentiating between oil- and gas-based commodities in the analysis of risk; it also uses more recent data.

The study will begin with a detailed analysis of pipeline safety in Canada, followed by a section analyzing the transportation of oil- and natural gas-based products by rail. The subsequent section will assess the risks of marine transportation of oil. The last section will compare the safety of pipelines, rail, and marine transport before concluding.

Pipeline Safety

For the past few years, Canada's Transportation Safety Board (TSB) has published detailed data on pipeline accidents and incidents[1] for Canada's federally regulated oil and natural gas pipelines (TSB, 2017). These data and other reports from the TSB are the source of the data used in our analysis.

There is a major concern with the pipeline data that must be raised at the outset: it is fragmented into accidents and incidents. The problem with this is that there can be overlap between the two definitions. For example, both accidents and incidents can result in the release of oil or natural gas. For this reason, we will group accidents and incidents together, focusing on pipeline "occurrences," which is a term that encompasses both.[2] Additionally, from 2004[3] to 2015, approximately 94 percent of pipeline occurrences were classified as incidents. If this study focused only on accidents, it could overestimate the safety of pipelines.

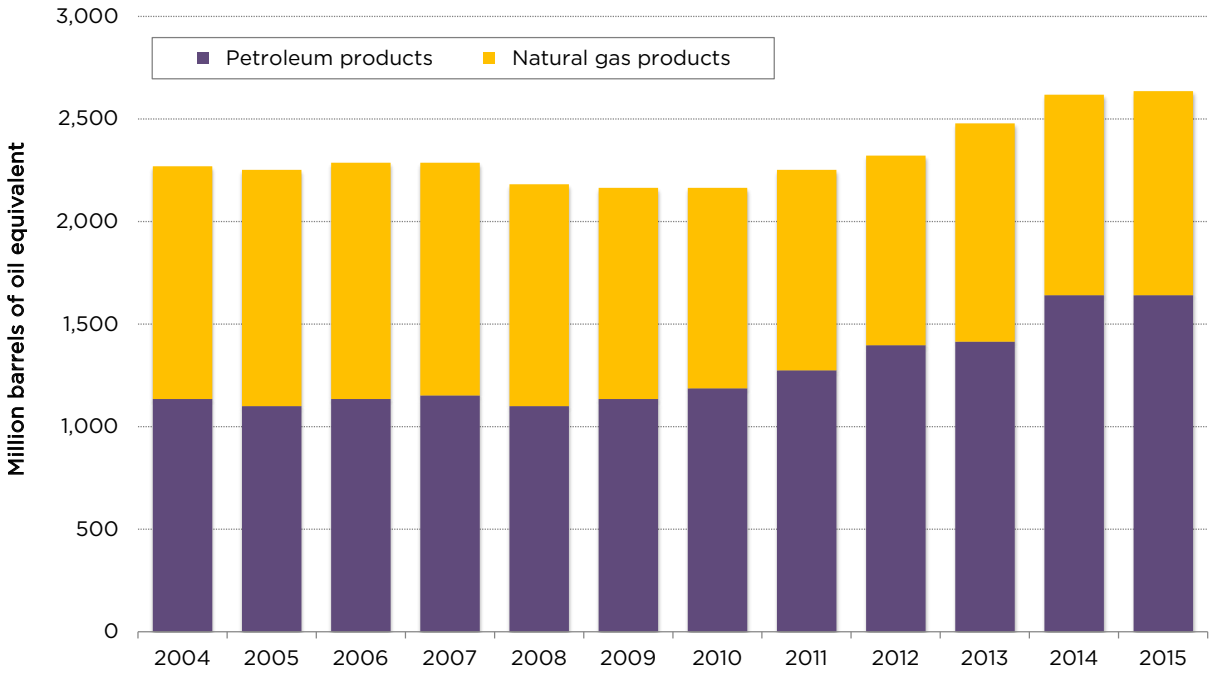
In order to assess the relative risk of pipelines and compare them to other modes of petroleum and natural gas transportation, the number of occurrences must be weighed against the amount of product transported. Figure 1 displays the volume of petroleum and natural gas products transported through the federally regulated system from 2004 to 2015. During this period, the volume of product transported increased from approximately 2.3 billion barrels of oil equivalent (Bboe) to over 2.6 billion Bboe, a growth of roughly 16 percent. The increased overall transportation volume is entirely the result of more petroleum products being moved, as fewer natural gas products were transported by this system in 2015 than in 2004. In total, from 2004 to 2015, the transportation of petroleum-based products grew by 45 percent.

[1] See the appendix for the complete definitions of accidents and incidents.

[2] The TSB also uses the occurrence terminology to refer to both accidents and incidents (TSB, 2016).

[3] The base year of this study is 2004, as this is the first year for which pipeline data can be broken down by the commodity groups being transported.

Figure 1: Amount of Petroleum and Natural Gas Based Goods Transported by Pipelines, 2004-2015 (million barrels of oil equivalent)



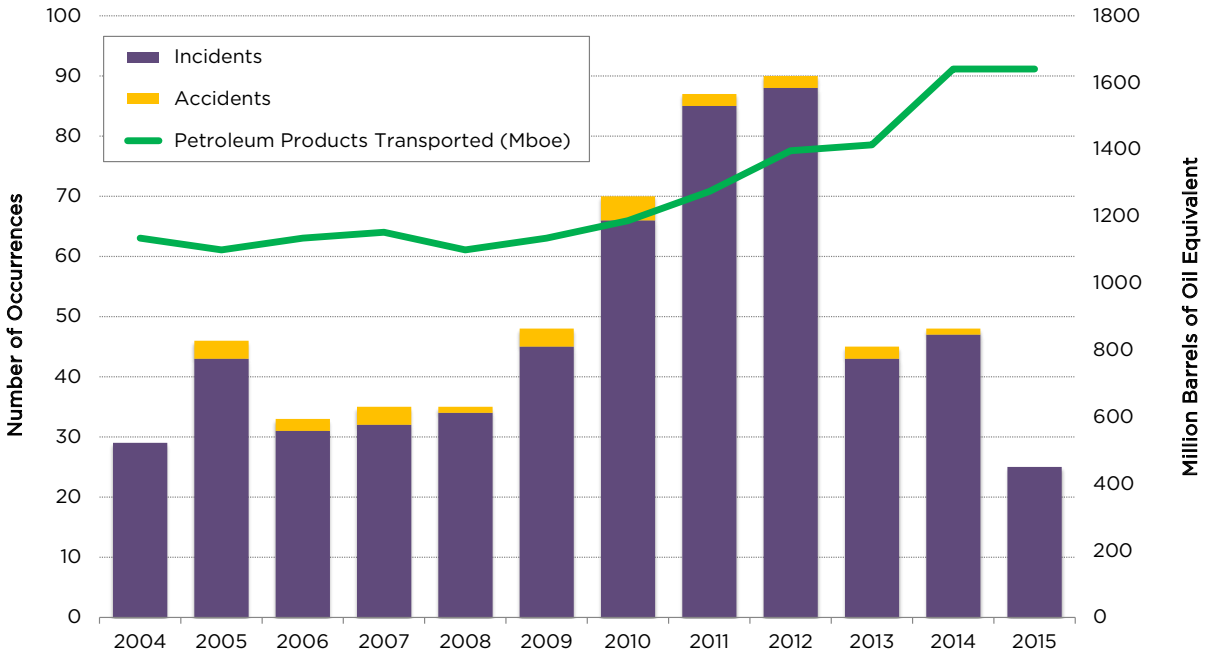
Sources: TSB (2016); authors calculations.

The next step in assessing the risk of pipelines is to analyze the number of occurrences that have resulted from transporting petroleum and natural gas products through pipelines.

Figure 2 gives a graphical depiction of the number of occurrences involving petroleum products from 2004 to 2015. On average, during this period, there were 49 occurrences each year involving pipelines transporting petroleum products, with 96 percent of the occurrences in this period being classified as incidents. As figure 2 also shows, in recent years, the safety of pipelines in the transport of petroleum products appears to be improving. Indeed, after steadily increasing from 33 occurrences in 2006 to 90 occurrences in 2012, the number of occurrences has fallen substantially since 2012, dropping to 25 occurrences in 2015. The increase in the number of occurrences up until 2012 appears to have been the result of a greater number of incidents; the number of accidents is relatively consistent over the analysis period.

Figure 3 displays the number of occurrences for pipelines carrying natural gas products over the study period. From 2004 to 2015, there was an average of 68 occurrences each year, the vast majority of which were incidents (over 90 percent). One intriguing insight based on the data from

Figure 2: Pipeline Accidents and Incidents Involving Petroleum Products, 2004-2015



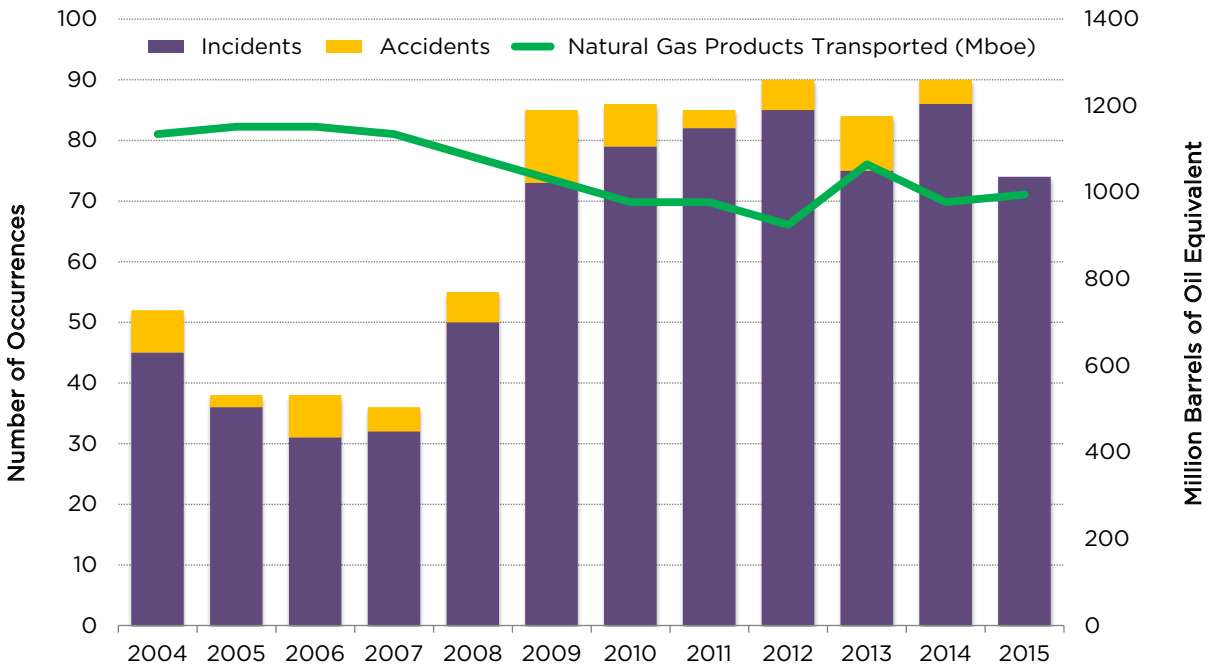
Sources: TSB (2016, 2017); authors calculations.

the TSB is that the number of occurrences with natural gas pipelines has increased substantially since 2009. Prior to 2009, there was an average of 44 occurrences per year. But from 2009 onwards, the average number occurrences per year totaled roughly 85 per year, an almost a 100 percent increase over the earlier period. This greater frequency of occurrences for pipelines carrying natural gas products also appears to be coming at a time when the federally regulated system is transporting smaller volumes of natural gas products than in the first few years in the analysis.

In a comparison of the number of occurrences resulting from the transport of petroleum versus natural gas products, petroleum product transport appears to result in fewer occurrences. For example, during the 12 years of the study period, the transportation of petroleum products resulted in an average of 49 occurrences per year, while the transportation of natural gas products by pipeline resulted in an average of 68 occurrences per year, or roughly 20 more occurrences per year than pipeline transportation of petroleum products.

In recent years, however, the divergence in safety between the two groups of commodities has been even starker. Focusing on the last five years of the analysis (since 2011), the average number of yearly occur-

Figure 3: Pipeline Accidents and Incidents Involving Natural Gas Products, 2004-2015



Sources: TSB (2016, 2017); authors calculations.

rences for pipelines transporting petroleum products was 59, versus 85 for natural gas products. It is important to note that not all of the occurrences for either petroleum or natural gas pipelines result in the release of oil or gas into the environment. Table 1 shows that approximately 81 percent of petroleum pipeline occurrences and 84 percent of natural gas occurrences result in the release of product.

While these percentages may seem alarming, these releases are usually relatively small. As figure 4 shows, 68 percent of all pipeline occurrences result in product releases of less than one cubic metre. Only two percent result in volumes in excess of 1,000 cubic metres of product being released. In addition, many of these sizeable releases are of natural gas products, which are more likely to dissipate because their volatile nature causes them to quickly evaporate into the air.

While broad comparisons of the simple number of accidents over a given period provide some insight into safety, they don't provide much context.

What matters the most when assessing safety, particularly relative to other commodities or modes of transportation, is the number of occurrences that occur for a given amount of product being transported. Table 2

Table 1: Pipeline Occurrences with Product Releases, 2004-2015

Percentage of Petroleum Occurrences with Release of Product	81%
Percentage of Natural Gas Occurrences with Release of Product	84%
Percentage of Total Pipeline Occurrences with Release of Product	83%

Source: TSB (2016, 2017); authors calculations.

displays the relative safety of transporting petroleum and natural gas products through pipelines and the relative risk of pipelines as a whole. Overall, pipelines experience approximately 0.05 occurrences per million barrels of oil equivalent (Mboe) transported. Recall that "occurrences" includes both incidents and accidents. The rate of incidents was much higher than the rate of accidents.

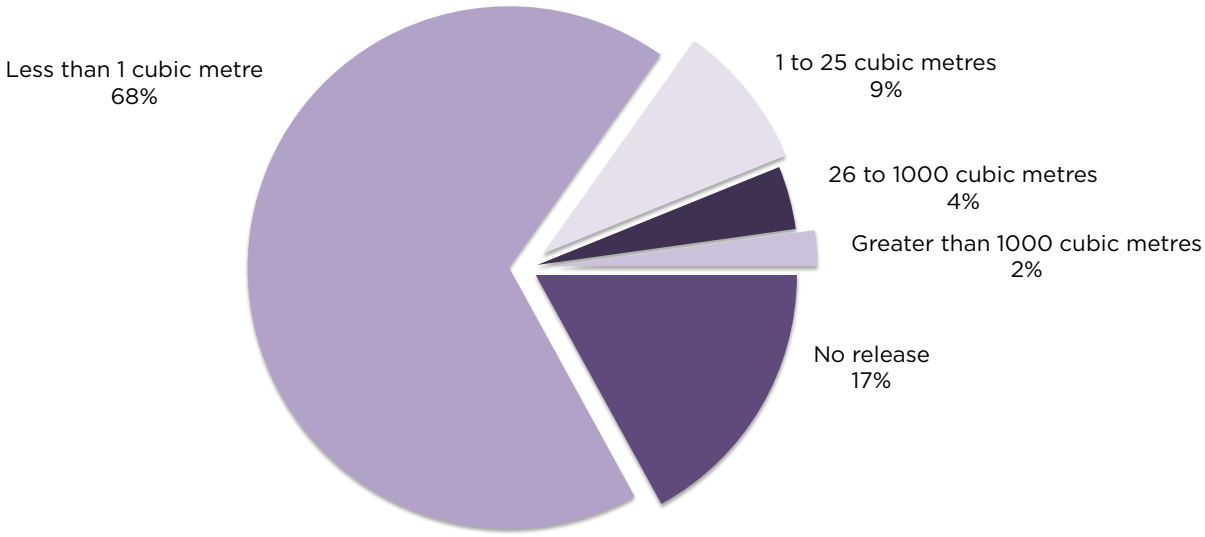
One key insight from the comparison in table 2 is the extent to which the pipeline transportation of petroleum products is safer than the transportation of natural gas products. Transporting petroleum products by pipelines resulted in approximately 0.04 occurrences per Mboe compared to 0.07 for natural gas products. This means that the rate of occur-

Table 2: Pipeline Occurrences per Million Barrels of Oil Equivalent Transported, 2004-2015

Petroleum Products		Natural Gas Products		Total Pipeline Goods	
Accidents	23	Accidents	65	Accidents	88
Incidents	568	Incidents	748	Incidents	1,316
Occurrences	591	Occurrences	813	Occurrences	1,404
Petroleum Goods Transported (Mboe)	15,309	Natural Gas Goods Transported (Mboe)	12,603	Pipeline Goods Transported (Mboe)	27,912
Accidents per Mboe	0.002	Accidents per Mboe	0.005	Accidents per Mboe	0.003
Incidents per Mboe	0.037	Incidents per Mboe	0.059	Incidents per Mboe	0.047
Occurrences per Mboe	0.039	Occurrences per Mboe	0.065	Occurrences per Mboe	0.050

Source: TSB (2016, 2017); authors calculations.

Figure 4: Pipeline Accidents and Incidents by Quantity Released, 2004-2015



Sources: TSB (2016); authors calculations.

rences for transporting natural gas products was 1.67 times greater than the rate of occurrences for petroleum products.

As mentioned above, the amount of product released from pipeline occurrences varies widely, with the vast majority of releases resulting in the dispersion of less than one cubic metre of product. Table 3 estimates the number of occurrences per Mboe for various spill volumes. It presents data for petroleum and natural gas products combined. The findings indicate that there are approximately 0.001 releases of product greater than 1,000m^3 per million barrels of product transported, or roughly one major release per billion barrels of product transported. If product is going to be released during an occurrence, it is far more likely that it will be less than one cubic metre. Based on the 12-year study period, there are approximately 0.034 occurrences resulting in a release less than one cubic metre per million barrels of product transported.

The relative rate of occurrences and the typical amount of product released are still only parts of a broader evaluation of pipeline safety. Table 4 presents additional measures to evaluate pipeline safety based on detailed data from the TSB (2017). The data in this table are expressed as a percentage of all occurrences. For example, only 17 percent of all pipeline occurrences take place in the actual line pipe. The vast majority of occurrences occur at facilities, which include for example, compressor stations,

Table 3: Pipeline Occurences by Release Volume per Million Barrels of Oil Equivalent Transported, 2004-2015

	Less than 1 cubic metre	1 to 25 cubic metres	26 to 1000 cubic metres	Greater than 1000 cubic metres
Occurrences	953	127	55	31
Pipeline Goods Transported (Mboe)	27,912	27,912	27,912	27,912
Occurrences per Mboe	0.034	0.005	0.002	0.001

Source: TSB (2016); authors calculations.

gas processing plants, pump stations, terminals, transmission line pig traps, etc. Spills that occur in these areas are often contained within the facility, which often have secondary containment mechanisms and procedures (Furchtgott-Roth and Green, 2013).

Another important takeaway from this table is that very few of the occurrences that do happen (0.6 percent) result in environmental damage. This number is particularly small considering that the vast majority of petroleum and natural gas products are transported through pipelines without any occurrences.

Table 4: Additional Statistics on Pipeline Safety by Commodity, 2004-2015

	Petroleum	Natural Gas	Total
Occurrences in Line Pipe	15.9%	17.8%	17.0%
Occurrences in Facilities	84.1%	81.4%	82.5%
Occurrences with Injuries	0.2%	0.2%	0.2%
Occurrences with Environmental Damage	1.0%	0.4%	0.6%
Occurrences with Fire	2.5%	9.6%	6.6%
Occurrences with Explosion	0.5%	0.7%	0.6%

Source: TSB, 2017.

Rail Safety

In recent years, the lack of available pipeline capacity led to higher volumes of petroleum goods being transported by rail. This has led to questions about the comparative level of safety between rail and pipelines (see Furchtgott-Roth and Green, 2013; and Green and Jackson, 2015).

This section examines the amount of product being transported, then presents an overview of rail accidents by commodity group and the relative risk estimates for rail safety. It also presents additional rail safety data.

We acquired the data on rail accidents through a special request to Transport Canada (2017). Only dangerous goods commodities that are also transported through pipelines were included in the analysis of rail safety.[4]

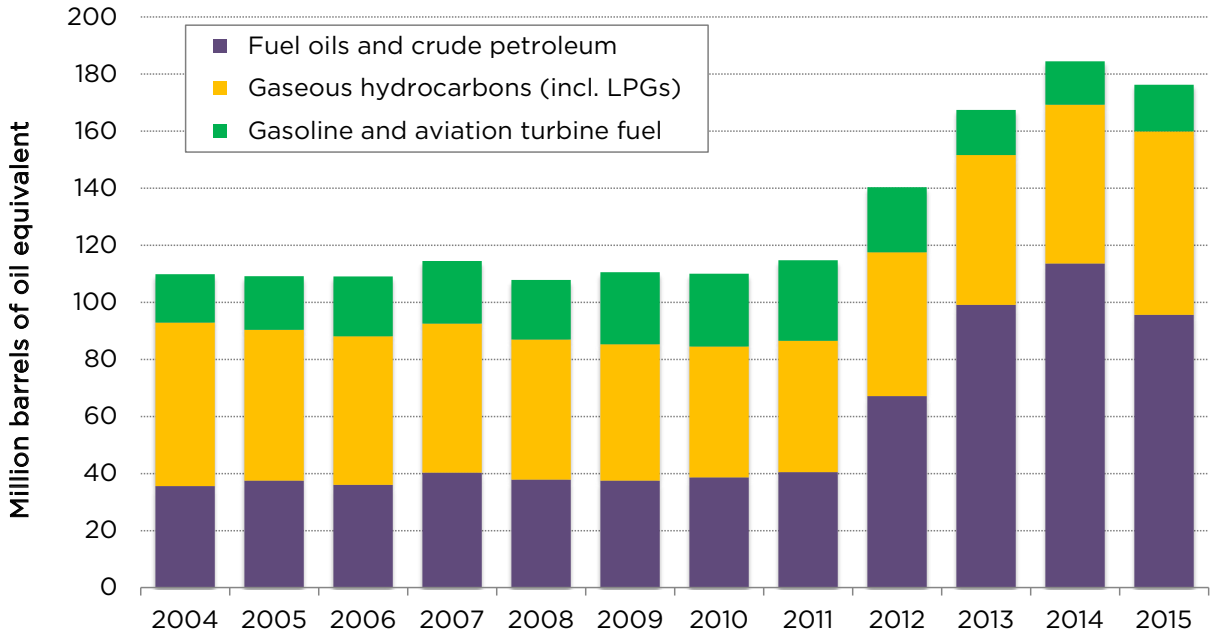
Figure 5 displays the data on the amount of petroleum and natural gas product transported by rail that are part of this analysis. The amount of gaseous hydrocarbons and gasoline and aviation turbine fuel transported by rail varied little from 2004 to 2015. However, the transportation of fuel oils and crude petroleum by rail increased greatly at the end of this period. Specifically, in 2004 only 36 Mboe were transported by rail, compared to 114 Mboe in 2014, the year that the largest volume of these products was transported by rail. A smaller amount of fuel oil and crude petroleum was transported in 2015.

Figure 6 displays the number of rail accidents involving petroleum products over the period of this study. The relatively small number of accidents prior to 2012 corresponds to the minimal amount of petroleum-based products that were transported during this period. From 2012 onward, however, as increasing amounts of petroleum were transported by rail, the number of rail accidents involving petroleum-based products increased substantially, peaking in 2013 at 22. The number of accidents did decline slightly in the two years after 2013.

Figure 7 displays the same data for natural gas products transported by rail. The pattern here appears to be the opposite of what it was for the rail transport of petroleum products. The number of rail accidents has

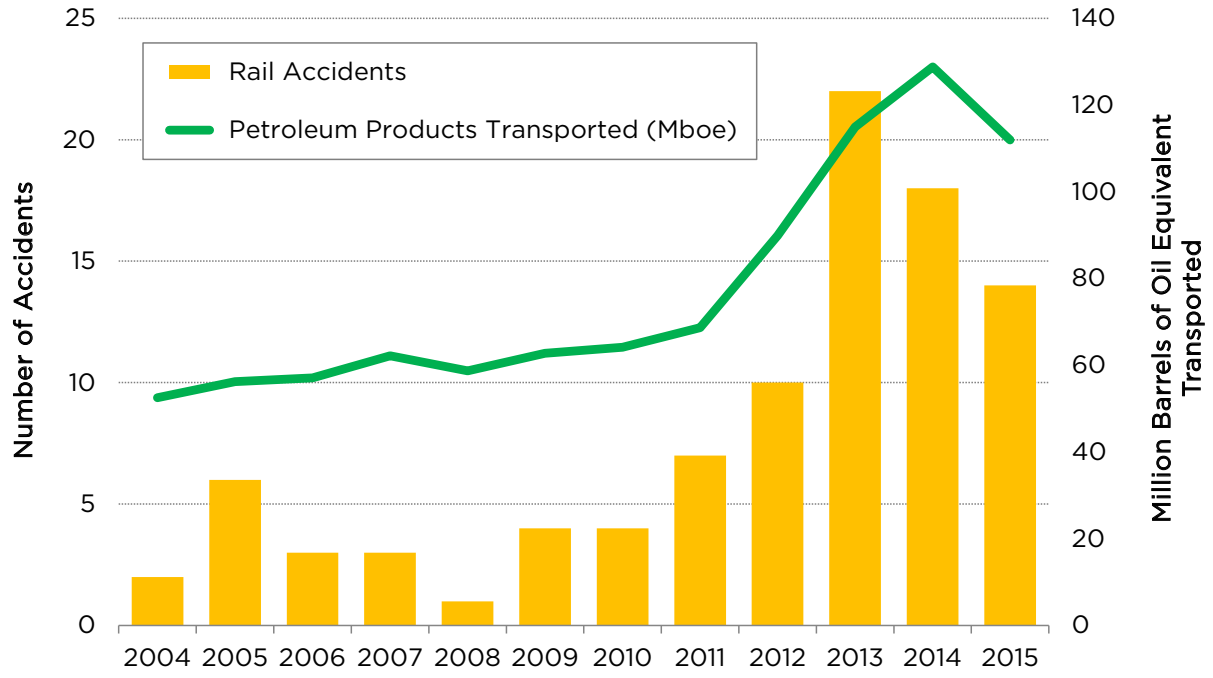
[4] See Green and Jackson (2015) for an overview of the commodities carried through each of the two modes of transportation.

Figure 5: Amount of Oil and Gas Transported by Rail, 2004-2015 (million barrels of oil equivalent)



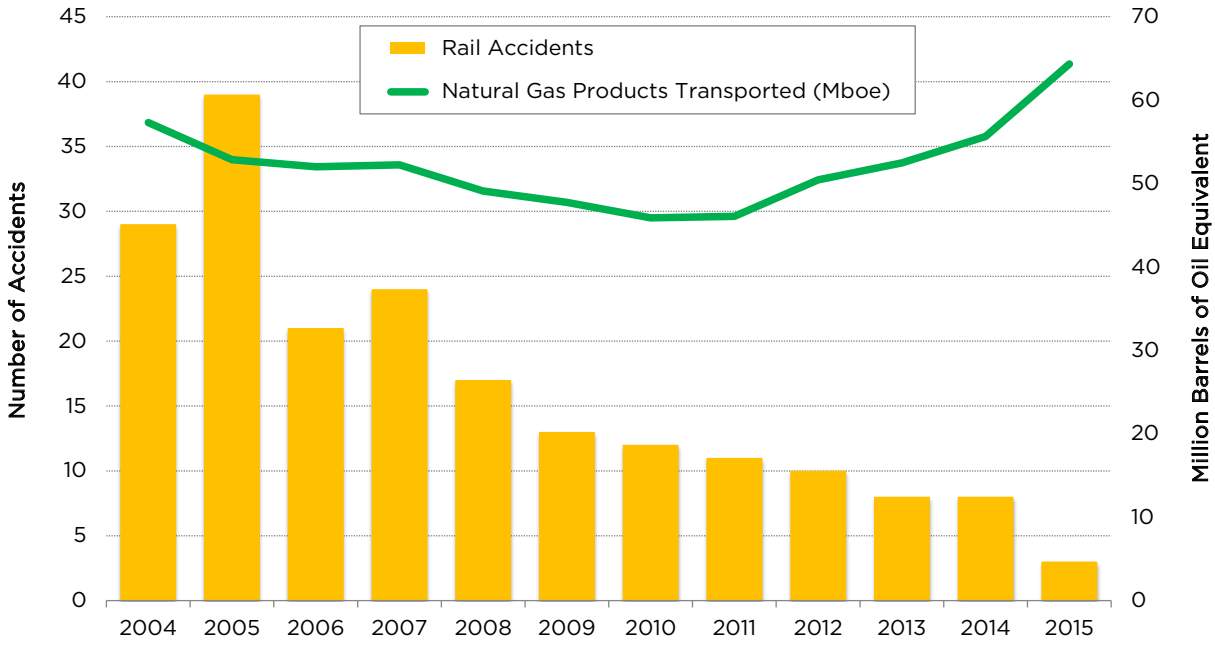
Sources: Statistics Canada, 2017.

Figure 6: Rail Accidents Involving Petroleum Products, 2004-2015



Sources: Transport Canada (2017); Statistics Canada (2017); authors calculations.

Figure 7: Rail Accidents Involving Natural Gas Products, 2004-2015



Sources: Transport Canada (2017); Statistics Canada (2017); authors calculations.

declined from a peak of 39 in 2005 to only three in 2015. Moreover, the amount of natural gas products being transported was generally consistent throughout the period, even slightly increasing in more recent years.

Parallel to the analysis of pipeline safety, we also estimated the accident rate for the rail transport of petroleum and natural gas products, accounting for the amount of the product being transported. As table 5 indicates, similar to pipelines, the risk of an accident per Mboe transported is quite small. From 2004 to 2015, there were approximately 0.186 accidents per Mboe of petroleum and natural gas products transported. Also similar to pipelines, accidents were less likely for transporting petroleum products by rail compared to transporting natural gas products by the same mode. This finding may be driven in large part by the greater number of accidents in the transport of natural gas products at the beginning of the study period.

Similar to our analysis of pipelines, the data compiled on rail safety also allowed for an analysis of the percentage of rail accidents resulting in the release of product and the percentage of accidents that occur in transit (similar to those that occur in line pipe in the pipeline analysis).

Table 5: Rail Accidents per Million Barrels of Oil Equivalent Transported, 2004-2015

Petroleum Products		Natural Gas Products		Total Rail Goods	
Accidents	94	Accidents	195	Accidents	289
Petroleum Goods Transported (Mboe)	928	Natural Gas Goods Transported (Mboe)	626	Rail Goods Transported (Mboe)	1,554
Accidents per Mboe	0.101	Accidents per Mboe	0.311	Accidents per Mboe	0.186

Source: Transport Canada (2017); Statistics Canada (2017); authors calculations

These percentages are displayed in table 6. At approximately 78 percent, the percentage of accidents involving petroleum products that resulted in a release was roughly comparable to what it was for pipelines (81 percent). However, compared to pipelines, rail accidents involving natural gas products were much less likely to result in a release.

As a percentage of accidents that occur in the actual transit of petroleum products, pipelines appear to perform better than rail. Specifically, approximately 16 percent of pipeline accidents involving petroleum-based products occurred in the line pipe, compared to 26 percent of rail accidents involving petroleum goods occurring in transit. Again, this means that a higher share of pipeline occurrences take place in facilities that likely have secondary containment mechanisms. In total, 19 percent of rail accidents involving petroleum and natural gas products occurred in transit.

Table 6: Additional Statistics by Commodity for Rail Transport, 2004-2015

Percentage of Petroleum Accidents with Release of Product	78%
Percentage of Natural Gas Accidents with Release of Product	65%
Percentage of Total Rail Accidents with Release of Product	69%
Percentage of Petroleum Accidents Occurring in Transit	26%
Percentage of Natural Gas Accidents Occurring in Transit	15%
Percentage of Total Rail Occurring in Transit	19%

Source: Transport Canada (2017); authours calculations.

Marine Safety

The approval of the Trans Mountain pipeline to BC's coast means that tanker safety will become an issue of increasing importance, as oil shipped through this pipeline will likely supply tankers that will transport it abroad. By one estimate, the number of oil tankers in Vancouver could increase from five to 34 per month (Johal and Meiszner, 2013, Oct. 15). The possibility of such a dramatic increase in tanker traffic is expected to contribute to increased concern about the safety of tankers for transporting oil.

In 2013, the federal government commissioned a panel to review the safety of marine-based oil transportation, the effectiveness of the current regulatory regime, and the preparedness of Canadian authorities to respond to spills (Houston, Gaudreau, and Sinclair, 2013). The work of that panel presents the best assessment of the risks posed by oil tankers in Canadian waters.

After the Exxon Valdez accident and oil spill, as well as a number of other oil spills around Canadian waters, the federal government issued a review of oil tanker safety that resulted in the establishment of the Shipsource Oil Spill Preparedness and Response Regime in the mid-1990s. Since then, there has not been a single major spill from oil tankers or other vessels in Canadian waters (Houston, Gaudreau, and Sinclair, 2013).[5]

As part of its assessment, the Houston, Gaudreau, and Sinclair (2013) panel attempted to estimate the probability of different types of spills occurring in Canadian waters using Canadian data. However, because no crude oil tanker had been involved in an oil spill in more than two decades, the panel had to use international data from the last 10 years to compute possible probabilities of oil spills. The lack of Canadian data from which they could compute these risk estimates is a testament to the

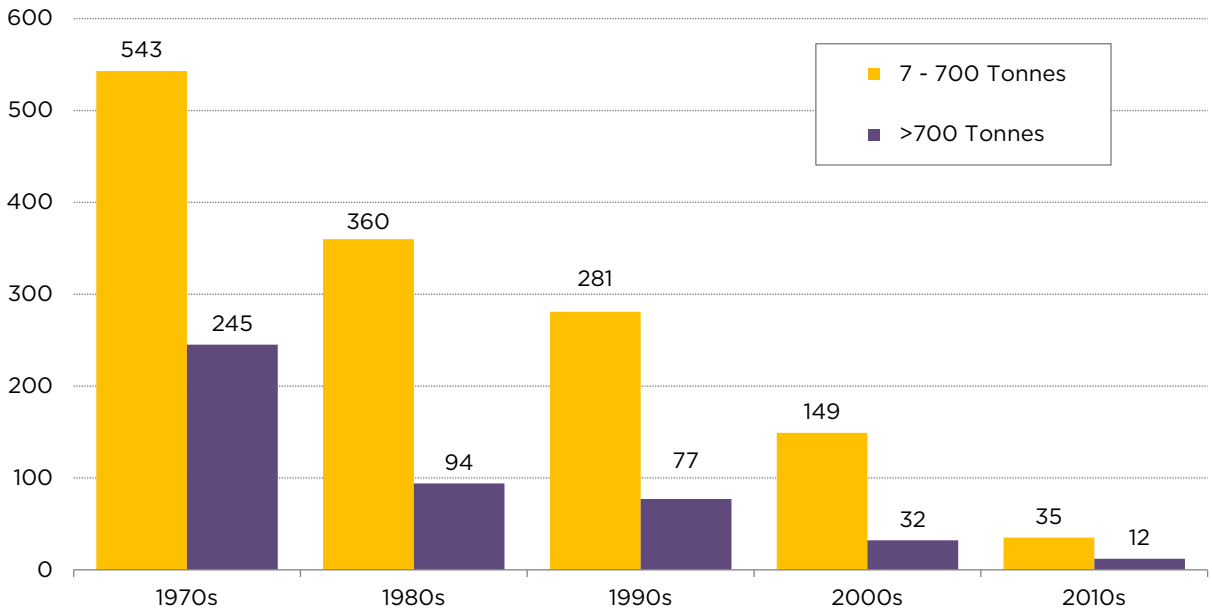
[5] While there have not been any major spills off of Canada's east and west coasts, there have been some minor spills, although none involve tankers. The largest spill on the east coast occurred in 2002 off of Conception Bay, Newfoundland, when a fishing vessel under tow sank releasing 365 tonnes of diesel. The largest spill off the west coast came in 2006 in Wright Sound, British Columbia, with the sinking of the Queen of the North ferry, which released 243 tonnes of bunker fuel (Houston, Gaudreau, and Sinclair, 2013).

Table 7: Estimated Number of Years Between Spills by Quantity Spilt

Volume, m^3	10 to 100	100 to 1,000	1,000 to 10,000	>10,000
Crude Tanker	46.4	69.2	51.6	242.3

Source: Houston, Gaudreau, and Sinclair (2013).

Figure 8: Number of Global Seaborne Oil Spills by Size, 1970-2016



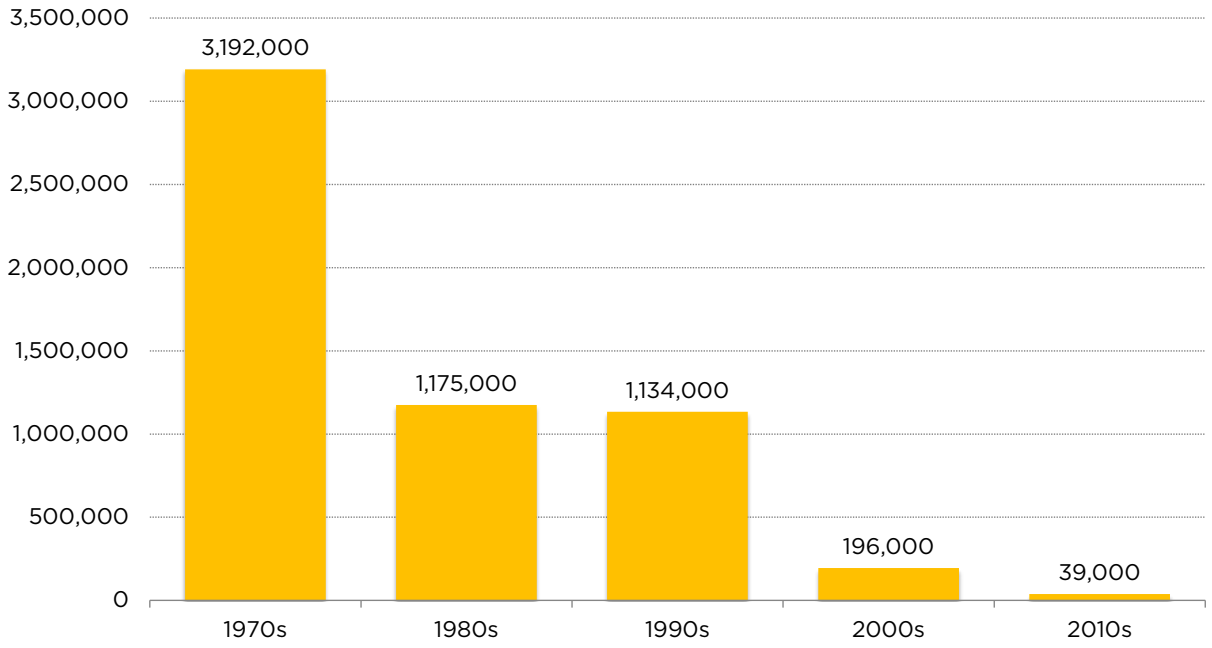
Source: ITOPF (2017).

functioning of the safety regime put in place in the mid-1990s and the extent to which it has made Canadian waters safer.[6]

Table 7 displays the number of years between spills for various quantities of oil spilled based on international data. This computation of spill risks indicates that a spill over 10,000 tonnes is estimated to occur

[6] Of course this does not mean that improvements should not be made and that the regime should not be modernized. Indeed, the Houston, Gaudreau, and Sinclair (2013) panel concluded with 45 recommendations for the government to implement that would help minimize future risks.

Figure 9: Quantity of Seaborne Oil Spilled, Tonnes, 1970-2016



Source: ITOPF (2017).

once every 242 years. Likewise, a spill of 100 to 1,000 tonnes is expected to occur once every 69.2 years.[7]

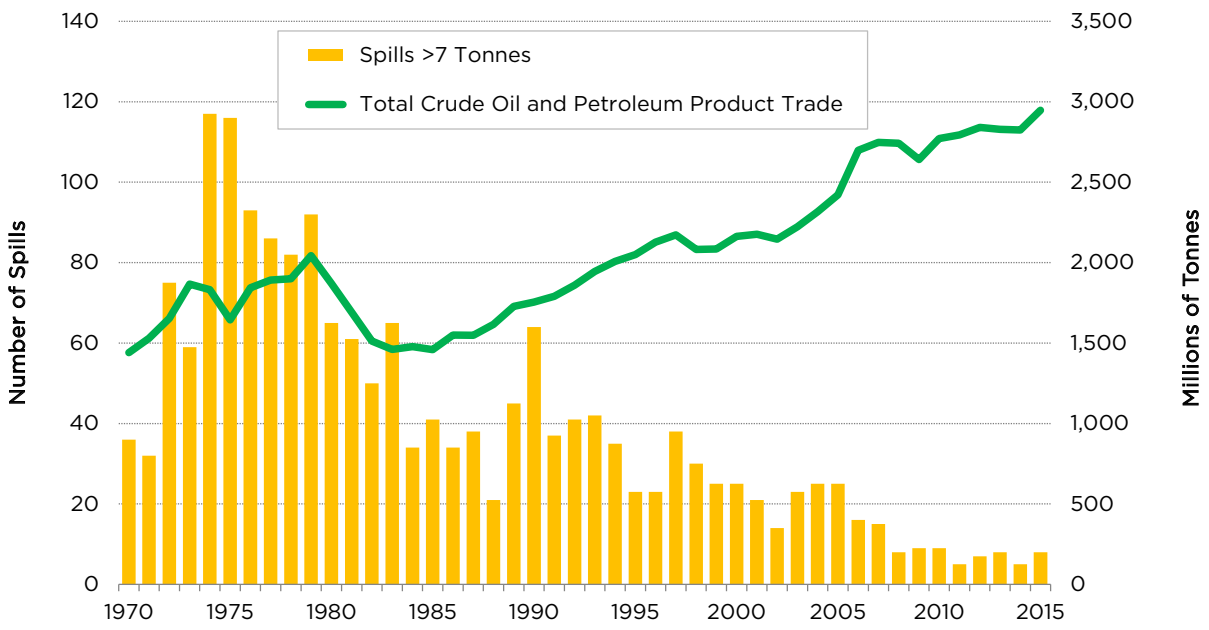
Given that data on tanker oil spills in Canada is sparse as there have been no major spills in over two decades, it is worthwhile to consider the international trends to try to get a better sense of tanker safety.

As figure 8 indicates, the number of seaborne oil spills globally has decline dramatically since the 1970s.When comparing the number of spills in the 1970s to those in the 2010s (up to 2016), spills between 7 and 700 tonnes have decreased from 543 to 35. In this same period, the number of large spills (over 700 tonnes) has declined from 245 to 12. Clearly there has been a demonstrable improvement in the risks associated with transporting oil by sea.

The improvements in safety can also be seen in the quantity of oil that has been spilled since the 1970s (figure 9). In the 1970s, over three million tonnes of oil was spilled into global waters—a significant amount

[7] Given that these estimates are based on international data, they could indicate that the risk of a spill is more frequent than is the actual risk within Canadian waters, since these results could be reflective of safety regimes in waters that are not regulated to the same extent as those under Canadian jurisdiction.

Figure 10: Number of Oil Spills Greater than 7 Tonnes vs. Global Seaborne Oil and Petroleum Product Trade, 1970-2015



Note: Petroleum product and gas includes LNG, LPG, naphtha, gasoline, jet fuel, kerosene, light oil, heavy fuel oil and others.

Source:s ITOPF (2017); UNCTAD (2016).

of pollution during this 10-year period. However, as is the case with the number of spills, significant reductions have been made in the amount spilled in the decades following the 1970s. For example, from 2010 to 2016, only 39,000 tonnes of oil was spilled globally. Another comparison that illustrates the dramatic decline in the amount of oil spilled during the transportation of this commodity is a comparison of the amount of oil spilled in the first and last year of our sample. In 1970, 383,000 tonnes of oil was released compared to only 6,000 in 2016.

The improvements in marine-based oil transportation safety have come about even though the amount of oil being transported has been increasing (see figure 10). Specifically, the amount of oil being transported worldwide has approximately doubled from 1975 to 2015, yet the number of accidents with spills larger than seven tonnes has dropped more than ten-fold, from 116 to 8.

In sum, similar to pipeline and rail transportation of Canadian petroleum and natural gas products, marine transport—both in Canada and internationally—appears to present small but real risks.

Comparing Modes of Transportation

This final section compares the relative safety of the three modes of transportation (pipeline, rail, and marine tanker) evaluated in this study.

Table 8 compares the occurrence and accident rates for pipelines and rail. When it comes to the transportation of both petroleum and natural gas commodities, pipelines were less likely to experience an occurrence per Mboe of product transported. Specifically, the likelihood of a rail accident was approximately 2.6 times greater than for pipelines per Mboe of petroleum product transported. Similarly, the likelihood of a rail accident occurring in the transportation of natural gas products was approximately 4.8 times greater than when similar commodities were transported through pipelines.

Table 9 presents the same comparison, but limits it to pipeline occurrences and rail accidents that resulted in the release of product. Between pipelines and rail, the release rates are slightly closer than the accident and occurrence rates. However, pipelines are still less likely to have a product release when transporting either oil or natural gas. Using the transport of petroleum products as an example, pipelines experienced 0.031 releases per million barrels of oil transported, whereas rail experienced 0.079 releases per million barrels of oil transported. This means that the likelihood of a product release was approximately 2.5 times greater when transporting a million barrels of oil by rail compared to pipelines.[8]

[8] To be clear, this is not a comparison of the amount of oil spilled when releases do occur. To our knowledge, the rail data do not exist in Canada to do such a comparison. Instead, the comparison is for the sheer number of releases. Some may point to the US State Department (2014) analysis of the Keystone XL pipeline, which found that rail transport compared to pipeline resulted in fewer barrels of oil being released, and used that as evidence that transporting oil by rail would actually result in smaller amounts of product being released. However, such a conclusion should be taken cautiously, as the State Department finding noted that the differences in total volume spilled between rail and pipelines could be offset, at least somewhat, by the increased likelihood that a spill will occur when oil is transported by rail.

Table 8: Comparison of the Risk of Transporting Petroleum and Natural Gas Products by Pipelines and Rail, 2004-2015

	Pipelines			Rail	
	Petroleum Products	Natural Gas Products		Petroleum Products	Natural Gas Products
Occurrences per Mboe	0.039	0.065	Accidents per Mboe	0.101	0.311

Source: TSB (2016, 2017); Transport Canada (2017); Statistics Canada (2017); authors calculations.

The comparison of the three transportation modes is based on data from 2004 to 2015 and focuses only on the transportation of petroleum-based goods. The absence of spills in more than two decades has led to a lack of Canadian data on crude tanker safety, so international data on tanker safety will be used as a proxy. In addition, since the international marine safety data we are using considers only the number of spills, not the total number of accidents, the pipeline and rail data will similarly be constrained to consider only pipeline occurrences or rail accidents in which product was released.

Table 10 provides a rough comparison of the relative safety of each mode of transportation. For petroleum transportation, marine tankers experienced the fewest releases per Mboe at roughly 0.001. This was followed by pipelines at 0.031 releases per Mboe of petroleum transported, and rail transportation, which resulted in approximately 0.079 releases per Mboe.

Table 9: Comparison of the Risk of Product Release When Transporting Petroleum and Natural Gas Products by Pipelines and Rail, 2004-2015

	Pipelines			Rail	
	Petroleum Releases	Natural Gas Releases		Petroleum Releases	Natural Gas Releases
Releases per Mboe	0.031	0.054	Releases per Mboe	0.079	0.201

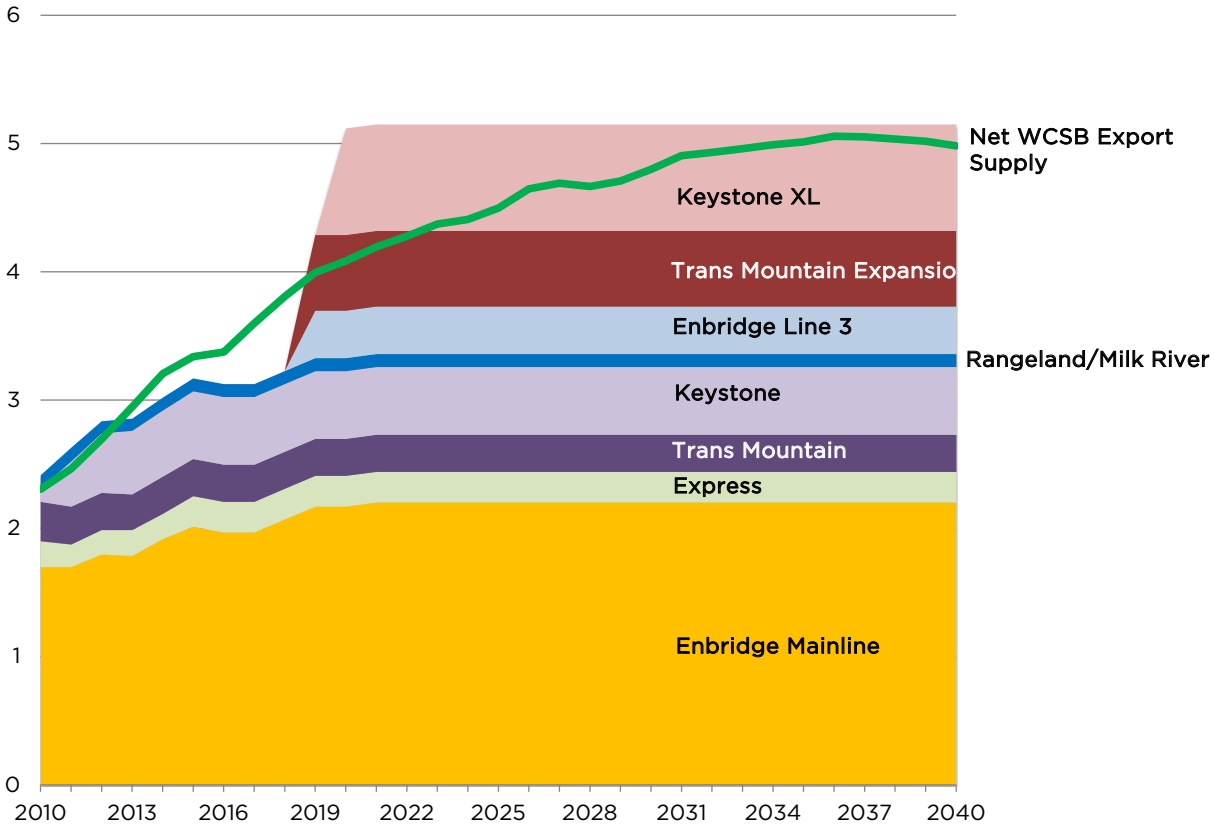
Source: TSB (2016, 2017); Transport Canada (2017); Statistics Canada (2017); authors calculations.

Table 10: Overall Comparison of the Relative Risk of Transporting Petroleum Products by Pipelines, Rail, or Marine Tanker, 2004-2015

Pipelines		Rail		Marine Tankers	
Occurrences with Release of Product	480	Accidents with Release of Product	73	Releases >7 Tonnes	140
Mboe Transported	15,309	Mboe Transported	928	Mboe Transported	238,811
Releases per Mboe	0.031	Releases per Mboe	0.079	Releases per Mboe	>0.001

Sources: TSB (2016, 2017); Statistics Canada (2017); Transport Canada (2017); ITOPF (2017); UNCTAD (2016); authors calculations.

Figure 11: WCSB Exporting Capacity Compared to Supply Forecasts, 2010 to 2040 (Million barrels of oil per day)



Sources: CAPP (2016); NEB (2016); author calculations.

Although the risks of petroleum being released when it is transported by rail are relatively small, of the three modes of transportation evaluated in this study, it is the one where a release is most likely to occur. However, recent pipeline approvals (assuming they proceed) make it less likely that there will be much future growth in the transport of these products by rail. Figure 8 illustrates pipeline capacity and the supply available for export[9] from the Western Canadian Sedimentary Basin (WCSB). As it shows, beginning in 2013, the available supply of oil exceeded export capacity. The dearth of pipeline capacity spurred the increased use of rail to transport the available oil to various destinations. As the new pipelines come online, supply projections predict that there will be adequate pipeline capacity, even in the long term, towards 2040. This is positive from a safety perspective as it means most Canadian oil will be traveling by the mode that is least likely to result in a release of potentially environmentally damaging products.

[9] The supply available for export is total supply minus Western Canadian refining capacity.

Conclusion

The economic rationale for added pipeline capacity is clear. Currently, Canadian oil is sold at a discount because it is not able to easily reach world markets where it would command a higher price. Angevine and Green (2016) estimated that at a world price of US$60 per barrel, exporting an additional one million barrels of oil per day could result in an incremental benefit of CA$4.1 billion annually.

However, although new pipelines have been approved, opposition to both their construction and the additional oil tanker traffic that would result from their completion remains fierce. The arguments against the pipelines are often rhetorical and hyperbolic rather than a reasoned analysis of the facts.

This study uses the most recently available data to assess the safety of the three dominant modes of oil and gas transport: pipelines, railways, and tanker ship. While the risks of accidents and possible releases are certainly real, they are quite small for all modes of transportation given the volume of these commodities that are moved. Of course, this does not mean that Canada should reduce or not strengthen its existing regulatory regimes surrounding the transportation of these products. However, the study does realistically assess the reality of the safety of oil and gas transportation.

One important conclusion from this study is that, while all transportation modes were found to be quite safe, some were safer than others. In particular, pipelines were found to be safer than rail for transporting petroleum, although marine transportation by tanker was found to be even safer than pipelines.

Canadians will accrue significant economic benefits from greater oil exports, which must be transported in the safest most environmentally friendly manner possible. The construction of new pipelines will help ensure that this is the case.

Appendix: Definitions of "Pipeline Accident" and "Pipeline Incident"

These definitions reflect those stated in TSB (2016).

"Pipeline accidents and incidents before 1 July 2014

Prior to July 2014 (previous TSB Regulations), pipeline accidents and incidents are defined as follows:

Pipeline accidents

"Reportable commodity pipeline accident" means an accident resulting directly from the operation of a commodity pipeline, where

- a person sustains a serious injury or is killed as a result of being exposed to
  - a fire, ignition or explosion, or
  - a commodity released from the commodity pipeline, or
- the commodity pipeline
  - sustains damage affecting the safe operation of the commodity pipeline as a result of being contacted by another object or as a result of a disturbance of its supporting environment;
  - causes or sustains an explosion, or a fire or ignition that is not associated with normal operating circumstances; or
  - sustains damage resulting in the release of any commodity.

Pipeline incidents

"Reportable commodity pipeline incident" means an incident resulting directly from the operation of a commodity pipeline, where

- an uncontained and uncontrolled release of a commodity occurs,
- the commodity pipeline is operated beyond design limits,
- the commodity pipeline causes an obstruction to a ship or to a surface vehicle owing to a disturbance of its supporting environment,
- any abnormality reduces the structural integrity of the commodity pipeline below design limits,

- any activity in the immediate vicinity of the commodity pipeline poses a threat to the structural integrity of the commodity pipeline, or
- the commodity pipeline, or a portion thereof, sustains a precautionary or emergency shut-down for reasons that relate to or create a hazard to the safe transportation of a commodity.

Pipeline occurrences after 1 July 2014

On 1 July 2014, the new reporting provisions of the TSB Regulations came into effect. According to section 4(1) of the TSB Regulations, the operator of a pipeline must report the following pipeline occurrences to the Board if they result directly from the operation of the pipeline:

- a person is killed or sustains a serious injury;
- the safe operation of the pipeline is affected by
  - » damage sustained when another object came into contact with it, or
  - » a fire or explosion or an ignition that is not associated with normal pipeline operations;
- an event or an operational malfunction results in
  - » an unintended or uncontrolled release of gas,
  - » an unintended or uncontrolled release of HVP hydrocarbons,
  - » an unintended or uncontained release of LVP hydrocarbons in excess of 1.5 m3, or
  - » an unintended or uncontrolled release of a commodity other than gas, HVP hydrocarbons or LVP hydrocarbons;
- there is a release of a commodity from the line pipe body;
- the pipeline is operated beyond design limits or any operating restrictions imposed by the National Energy Board;
- the pipeline restricts the safe operation of any mode of transportation;
- an unauthorized third party activity within the safety zone poses a threat to the safe operation of the pipeline;
- a geotechnical, hydraulic or environmental activity poses a threat to the safe operation of the pipeline;
- the operation of a portion of the pipeline is interrupted as a result of a situation or condition that poses a threat to any person, property or the environment; or
- an unintended fire or explosion has occurred that poses a threat to any person, property or the environment.

Pipeline accidents after 1 July 2014

For 2014 statistical reporting, pipeline accidents as of 1 July 2014 consist of reportable pipeline occurrences that resulted in

- loss of human life;
- a serious injury;
- a fire or explosion that causes a pipeline or facility to be inoperative;
- a low vapour pressure hydrocarbon release in excess of 1.5 m^3 that leaves company property or the right-of-way;
- a rupture; or
- a toxic plume.

Pipeline incidents after 1 July 2014

For 2014 statistical reporting, pipeline incidents as of 1 July 2014 consist of all reportable pipeline occurrences other than pipeline accidents."

References

Angevine, Gerry, and Kenneth P. Green (2016). *The Costs of Pipeline Obstructionism*. The Fraser Institute. <https://www.fraserinstitute.org/sites/default/files/costs-of-pipeline-obstructionism.pdf>, as of May 15, 2017.

Canadian Association of Petroleum Producers [CAPP] (2016). *2016 Crude Oil Forecast, Markets and Transportation.* CAPP. <http://www.capp.ca/publications-and-statistics/crude-oil-forecast>, as of May 15, 2017.

Furchtgott-Roth, Diana, and Kenneth P. Green (2013). *Intermodal Safety in the Transport of Oil*. Fraser Institute. <https://www.fraserinstitute.org/sites/default/files/intermodal-safety-in-the-transport-of-oil-rev3.pdf>, as of May 15, 2017.

Green, Kenneth P., and Taylor Jackson (2015). *Safety in the Transportation of Oil and Gas: Pipelines or Rail?* Fraser Institute. <https://www.fraserinstitute.org/sites/default/files/safety-in-the-transportation-of-oil-and-gas-pipelines-or-rail-rev2.pdf>, as of May 1, 2017.

Houston, Gordon, Richard Gaudreau, and Michael Sinclair (2013). *A Review of Canada's Ship-Source Oil Spill Preparedness and Response Regime: Setting the Course for the Future*. Tanker Safety Panel Secretariat. <https://www.tc.gc.ca/media/documents/mosprr/transport_canada_tanker_report_accessible_eng.pdf>, as of May 15, 2017.

International Tanker Owners Pollution Federation [ITOPF] (2017). *Oil Tanker Spill Statistics, 2016*. ITOPF. <http://www.itopf.com/fileadmin/data/Photos/Publications/Oil_Spill_Stats_2016_low.pdf>, as of May 15, 2017.

Johal, Jas, and Peter Meiszner (2013, October 15). Kinder Morgan: Pipeline expansion will increase tanker traffic nearly seven-fold. *Global News*. <http://globalnews.ca/news/900601/kinder-morgan-pipeline-expansion-will-increase-tanker-traffic-nearly-seven-fold/>, as of May 15, 2017.

National Energy Board [NEB] (2016). *Canada's Energy Future 2016: Update—Energy Supply and Demand Projections to 2040* (October). Government of Canada. <https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016updt/index-eng.html>, as of May 15, 2017.

Statistics Canada (2017). *Table 404-0002: Railway Carloadings Statistics, by Commodity*. Government of Canada. <http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=4040002>, as of May 15, 2017.

Transport Canada (2017). Special data request from Transport Canada. Received on April 23, 2017.

Transportation Safety Board of Canada [TSB] (2016). *Statistical Summary–Pipeline Occurrences 2015*. Government of Canada. <http://www.tsb.gc.ca/eng/stats/pipeline/2015/ssep-sspo-2015.asp>, as of May 15, 2017.

Transportation Safety Board of Canada [TSB] (2017). *Pipeline Occurrence Data from January 2004*. Government of Canada. <http://www.tsb.gc.ca/eng/stats/pipeline/index-ff.asp>, as of May 15, 2017.

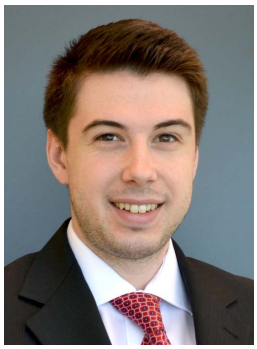
United Nations Conference on Trade and Development [UNCTAD] (2016). *World Seaborne Trade by Types of Cargo, by Country Groups and by Regions, Annual, 1970-2015*. UNCTAD. <http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=32363>, as of May 15, 2017

United States Department of State (2014b). *Final Supplemental Environmental Impact Statement: Keystone XL Project. Chapter 5.3: Comparison of Alternatives*. US Department of State. <https://2012-keystonepipeline-xl.state.gov/documents/organization/221198.pdf>, as of May 31, 2017.

About the Authors

Kenneth P. Green

Kenneth P. Green is Senior Director of Natural Resources at the Fraser Institute. He received his doctorate in Environmental Science and Engineering from the University of California, Los Angeles (UCLA), an MS in Molecular Genetics from San Diego State University, and a BS Biology from UCLA. Dr. Green has studied public policy involving risk, regulation, and the environment for more than 16 years at public policy research institutions across North America. He has an extensive publication list of policy studies, magazine articles, opinion columns, book and encyclopedia chapters, and two supplementary text books on climate change and energy policy. Ken's writing has appeared in major news papers across the US and Canada, and he is a regular presence on both Canadian and American radio and television.



Taylor Jackson

Taylor Jackson is a Senior Policy Analyst in the Centre for Natural Resource Studies at the Fraser Institute. He holds a BA and an MA in Political Science from Simon Fraser University. Mr. Jackson is the co-author of a number of Fraser Institute studies, including *Safety in the Transportation of Oil and Gas: Pipelines or Rail?*, and the Fraser Institute's annual *Global Petroleum Survey* and *Survey of Mining Companies*. Mr Jackson's work has been covered in the media all around the world and his commentaries have appeared in the *National Post*, *Financial Post*, and W*ashington Times*, as well as other newspapers across Canada.

Acknowledgments

The authors would like to thank the unidentified reviewers for their comments and insights, which improved the paper substantially. Any remaining errors or oversights are the sole responsibility of the authors. As the researchers have worked independently, the views and conclusions expressed in this paper do not necessarily reflect those of the Board of Directors of the Fraser Institute, the staff, or supporters.

Publishing information

Distribution

These publications are available from <http://www.fraserinstitute.org> in Portable Document Format (PDF) and can be read with Adobe Acrobat® or Adobe Reader®, versions 8 or later. Adobe Reader® DC, the most recent version, is available free of charge from Adobe Systems Inc. at <http://get.adobe.com/reader/>. Readers having trouble viewing or printing our PDF files using applications from other manufacturers (e.g., Apple's Preview) should use Reader® or Acrobat®.

Ordering publications

To order printed publications from the Fraser Institute, please contact:

- e-mail: sales@fraserinstitute.org
- telephone: 604.688.0221 ext. 580 or, toll free, 1.800.665.3558 ext. 580
- fax: 604.688.8539.

Media

For media enquiries, please contact our Communications Department:

- 604.714.4582
- e-mail: communications@fraserinstitute.org.

Copyright

Date of issue

July 2017

ISBN

978-0-88975-448-5

Citation

Green, Kenneth P., and Taylor Jackson (2017). *Safety First: Intermodal Safety for Oil and Gas Transportation*. Fraser Institute. <http://www.fraserinstitute.org>.

Supporting the Fraser Institute

To learn how to support the Fraser Institute, please contact

- Development Department, Fraser Institute
  Fourth Floor, 1770 Burrard Street
  Vancouver, British Columbia, V6J 3G7 Canada
- telephone, toll-free: 1.800.665.3558 ext. 548
- e-mail: development@fraserinstitute.org
- website: <http://www.fraserinstitute.org/donate>

Purpose, funding, and independence

The Fraser Institute provides a useful public service. We report objective information about the economic and social effects of current public policies, and we offer evidence-based research and education about policy options that can improve the quality of life.

The Institute is a non-profit organization. Our activities are funded by charitable donations, unrestricted grants, ticket sales, and sponsorships from events, the licensing of products for public distribution, and the sale of publications.

All research is subject to rigorous review by external experts, and is conducted and published separately from the Institute's Board of Trustees and its donors.

The opinions expressed by authors are their own, and do not necessarily reflect those of the Institute, its Board of Trustees, its donors and supporters, or its staff. This publication in no way implies that the Fraser Institute, its trustees, or staff are in favour of, or oppose the passage of, any bill; or that they support or oppose any particular political party or candidate.

As a healthy part of public discussion among fellow citizens who desire to improve the lives of people through better public policy, the Institute welcomes evidence-focused scrutiny of the research we publish, including verification of data sources, replication of analytical methods, and intelligent debate about the practical effects of policy recommendations.

About the Fraser Institute

Our mission is to improve the quality of life for Canadians, their families, and future generations by studying, measuring, and broadly communicating the effects of government policies, entrepreneurship, and choice on their well-being.

Notre mission consiste à améliorer la qualité de vie des Canadiens et des générations à venir en étudiant, en mesurant et en diffusant les effets des politiques gouvernementales, de l'entrepreneuriat et des choix sur leur bien-être.

Peer review—validating the accuracy of our research

The Fraser Institute maintains a rigorous peer review process for its research. New research, major research projects, and substantively modified research conducted by the Fraser Institute are reviewed by experts with a recognized expertise in the topic area being addressed. Whenever possible, external review is a blind process. Updates to previously reviewed research or new editions of previously reviewed research are not reviewed unless the update includes substantive or material changes in the methodology.

The review process is overseen by the directors of the Institute's research departments who are responsible for ensuring all research published by the Institute passes through the appropriate peer review. If a dispute about the recommendations of the reviewers should arise during the Institute's peer review process, the Institute has an Editorial Advisory Board, a panel of scholars from Canada, the United States, and Europe to whom it can turn for help in resolving the dispute.

Editorial Advisory Board