Quantitative comparison between pipeline and rail crude transportation cost to the society

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Abstract:

In the last decade, the movement of petroleum products, particularly crude oil, have received enormous public and media attention. Most of this attention has focused on major oil spills and accidents - raising the need to have a comprehensive assessment of the costs associated with the petroleum products transportation to society. This paper combines most recent available estimates of the costs of air pollution, greenhouse gases, spill and accident costs associated with the long-distance movement of petroleum products. The purpose of this paper is to provide a comprehensive quantitative cost comparison between transporting petroleum products by rail and pipeline to the society. We found that pipelines outperform rail on air pollution, greenhouse gases and costs associated with spills and accidents close to 2.5:1 in Canadian dollars (510 CAD vs 1248 CAD).

1.0 Introduction

Access to cheap and reliable energy is crucial to the continued growth of the North American and Canadian economies. Oil and gas are both reliable and relatively cheap energy sources. The efficient transportation to the consumption points, as well as export locations of these hydrocarbon products, ensures that Canadians can sustain their lifestyles while creating high-paying jobs, as well as reinvesting back into the economy through royalties and taxation.

In the last decade, the movement of petroleum products, particularly crude oil, have received enormous public and media attention. Most of this attention has focused on major oil spills and accidents, raising the need to have a comprehensive assessment of the costs associated with the petroleum products transportation to society. This paper combines the most recent available cost estimates of air pollution, greenhouse gases, and spill and accident costs associated with the long-distance movement of petroleum products, as well as the effects on other industries. The purpose of this paper is to provide a comprehensive quantitative cost comparison between transporting petroleum products by rail and pipeline to society.

Canada transports large amounts of oil and gas across expansive distances through its territory to help meet its domestic and international energy needs. In 2016, petroleum production in Canada was close to 3.85 million barrels per day (b/d) and is projected to climb to 5.12 million by 2030 (CAPP, 2018). Transporting these products in the most efficient and safest manner allows for increased domestic crude oil production and provides consumers worldwide with access to affordable energy. There are four main methods of transporting oil in Canada: pipeline, rail, boat, and road transportation by truck. For the purposes of this study, we focus solely on pipeline and rail transportation. We will analyse the two inland transportation methods' economic impact, safety record, and effect on the environment to come up with an estimate of the cost-to-society, and to determine which method can transport oil in the most cost-effective manner.

Pipeline is the most commonly used method for transporting oil in Canada. Over 75 per cent of all domestically produced petroleum liquids are transported by pipeline. There are currently 119,000 kilometers of liquid petroleum pipelines throughout Canada that transport 3.45 million barrels of oil per day (CEPA, 2018). Transportation by rail is the most commonly used alternative to pipeline transportation. Since the discovery of new unconventional plays in Canada and USA, as well as increased production from the oil sands, the use of rail to transport crude oil has increased dramatically. According to data from the National Energy Board, in 2012, 16 million barrels of oil were exported to USA by rail. By 2014, that number increased to 59 million barrels. Although that number decreased to 48 million in 2017, the competitive advantages offered by rail – its access to remote regions, as well as a relative lack of regulatory and social challenges often associated with the construction of new pipelines – will likely make it a viable transportation method for years to come. Both forms of transportation play a role in moving oil efficiently, but each has its unique trade-offs in terms of benefits it offers and the cost-to-society it implies.

2.0 Background

According to a recent report by the International Energy Agency (IEA) (2017), the world will need 30 per cent more energy by 2040 than we use today, and oil is expected to supply 27 per cent of the global energy demand. This includes an increase in oil consumption of 10 per cent over the next 22 years. This forecast is based on the assumption that countries will enact lower-carbon policies to fulfill commitments made in December 2015 at the United Nations Climate Change conference.

Canada has the third largest crude oil reserves in the world and is ranked as the sixth largest global oil producer. In 2016, Canada produced 3.85 million b/d of crude oil equivalent, including pentanes and condensates (Table 1). The Canadian Association of Petroleum Producers (CAPP) estimates show that total oil production is expected to grow from 3.85 million b/d in 2016 to 5.12 million b/d by 2030 (Table 1). Since the oil sand resource and the major conventional oil fields are all located in Western Canada, over 95% of all oil produced in Canada is coming from this region. The predicted production growth is also expected to come from mostly this area. Table 2 shows current production and forecast for Western Canada oil. It is worth mentioning that although Canada has significant amount of Unconventional Light Oil (ULO) and has been significantly explored, prediction about this resource is not fully reflected in the forecast because it is still in the early stage of development.

Canada is the largest foreign supplier of the heavy oil to the US refineries. Ninety-nine per cent of 3.1 million b/d of Canadian crude oil exports in 2016 went to the US. According to the IEA, by 2020, China and India will become two largest importers of crude oil in the world and Canada will benefit from having an opportunity to sell our crude to those markets.

Pipeline and rail crude oil transportation are regulated by different government bodies in Canada. National Energy Board is the national energy regulator, established to regulate the construction, operation and abandonment of pipelines that cross provincial or international borders (NEB 2016). Transportation of dangerous goods by rail is regulated by the Transport Canada.

3.0 Data

Pipelines: National Energy Board (NEB), Canada's Transportation Safety Board (TSB) and United States Pipeline and Hazardous Materials Safety Administration (PHMSA) publish detailed data on pipeline accidents and incidents for Canada's and US federally regulated oil and natural gas pipelines (TSB, 2017). These data from TSB and PHMSA and economic reports from The National Bureau of Economic Research (in reference) are the source of the data used in our analysis. Important to notice that due to overlap between incidents and accidents definitions we will be using occurrences as primary number in our estimates. Table 4 summarizes all of the major pipelines regulated by the NEB.

Rail: By special request to Transport Canada, we acquired data for the number of reportable occurrences[1] related to petroleum products transported by rail between 2007 and 2016. Only petroleum commodities that are transported by pipeline were used in the comparative analysis[2] (i.e., no ethanol). Access to Transport Canada's 2016 Statistical Addendum provided tonnage data for crude oil and other petroleum products, as well as total mileage data for all goods in the form of million-train-miles (MTM). The MTM includes both main track-miles and yard switching miles for 2008 to 2016.

4.0 Methodology

To compare cost to society associated with pipeline and rail crude oil and other petroleum liquids transportation we define cost to society. Cost to society is a combination of greenhouse gases, air pollution and spills and occurrences per million-barrel miles transported costs in Canadian dollars.

Air Pollution: Pollution emissions for pipelines and and rail differ from one another in three important ways. First, while emissions from pipelines occur at the power stations that generate

[1] Reportable occurrences defined as those consisting of an accidental release of dangerous goods greater than the quantity specified (200 L for all Class 3 Flammable Liquids) in Part 8 of the Transportation of Dangerous Goods Regulations (but has since been updated to require lower thresholds for reportable releases) (Transport Canada, 2016).

[2] Occurrences are based on commodities under the following UN classification: UN1075, UN1202, UN1203, UN1267, UN1268, UN1863, UN1971, UN1972, UN1993, UN3295, AND UN3494.

the electricity consumed, train emissions occur along the transportation route. Second, the power plants are typically located in less densely-populated areas, while the existing railroad infrastructure tend to go through populated areas. Third, emissions generated on a ground level by locomotives are more harmful than the same level of emissions released at the power stations. (Muller et at., 2009). For rail and pipeline related air pollution we use estimates from the National Bureau of Economic Research (Clay et al., 2017) converted into Canadian dollar.

Greenhouse gases: Similar to air pollution for rail related greenhouse gas emissions we use estimates from the National Bureau of Economic Research (Clay et al., 2017) for the North Dakota - Gulf of Mexico route due to similarity of population density along the route compared to Canada.[2] In that study cost of carbon was assumed to be 43 usd per tonne, while we assumed 50 CAD per tonne as a base case for our assumptions. For pipelines we adjust the number derived in the National Bureau of Economic Research to account for different profile of electricity generation between United States and Canada. In US 65% of the electricity is being produced from greenhouse emitting source, while in Canada only 20.2% of the electricity is being produced from Coal, Natural Gas or Oil. We conservatively estimate greenhouse emissions for the major pipelines in Canada to be close to 3 times lower than in USA due to difference in the sources of electricity generation between two countries.

Spills and Occurrences:

Using the data collected from TSB we weigh the number of occurrences per million-barrel miles for pipelines and comparing it to the same number for rail. US Pipeline safety regulations define “High Consequence Areas” (HCAs), as areas where pipeline passes close to populated areas, drinking water sources and unusually sensitive ecological resources. In our study we conservatively assume 60% of the pipelines pass to be

Figure (1) is the amount of crude oil and petroleum products transported by rail. So, the data for petroleum products were is Thousands of Tonnes. we used an average conversion factor to convert them to barrel of oil equivalent. As for the rate of occurrences, what we need is the number of occurrences divided by the amount of dangerous goods transported by rail. In the Figure (2), the number of reportable occurrences and their rates per one million barrel of oil equivalent is shown. The next Figure (3) is rate of occurrences in one million barrel train mile for years 2008 to 2016 . In order to estimate these values, we should figure it out how we can estimate the distance at which crude oil has been transported. Then we came up with this idea to use a fraction of dangerous goods to total goods transported by rail in each year. Having done this, we divided the accident rates per Mboe by the distance related to crude oil transportation. To have an average number of accident rate by year, we considered all the occurences and the volume transported in the 2008-2016 period which are shown in Table 5.

5.0 Results and Discussion

Table 8 presents our estimate of the average costs associated with greenhouse gases, air pollution and spills and occurrences per million-barrel miles for long distance transportation of crude oil. For movement of the crude oil, cost of greenhouse gases by rail, 200 CAD, is twice the cost compared to pipeline, 100 CAD. The air pollution damages are larger for the rail crude transportation compared to damages associated with pipeline (563 CAD vs 347 CAD). This are

Canada and USA wide averages and to be properly assessed for individual project need to be evaluated based on the population density. Spills and occurrences costs are also significantly higher for rail, compared to pipelines due to more expensive consequences associated with train disasters as well as more often occurring spills (483 CAD vs 63 CAD). Finally, total cost to society per million-barrel miles is 510 CAD for pipeline and 1248 CAD for rail.

6.0 Conclusion

This article uses data on crude oil and petroleum liquids transportation across Canada between 2007 and 2017 to examine the cost to society costs for movement of petroleum products by pipeline and rail. We found that pipelines outperform rail on air pollution, greenhouse gases and costs associated with spills and occurrences. Further, we notice that sum of greenhouse gases and air pollution for both pipelines and rail is larger than costs associated with spills and occurrences. These observations suggest that public and policy debate surrounding oil transportation is disproportionately puts too much attention on accidents instead of concentrating on more materially important parameters like air pollution and greenhouse gas emissions. Combined with higher cost of transporting crude oil for operators, pipelines seem to be a safer and economically more sound option for both society and operators for the long-distance transportation of the petroleum products.

7.0 Tables and Figures

Table 1. Canadian crude oil production

Million b/d	2016	2020	2025	2030
Eastern Canada	0.21	0.28	0.29	0.19
Western Canada	3.64	4.34	4.59	4.93
Total Canada	3.85	4.62	4.88	5.12

Table 2. Western Canada crude oil production

Million b/d	**2016**	**2020**	**2025**	**2030**
Conventional (including pentanes and condensate)	1.24	1.22	1.24	1.26
Oil sands (bitumen and upgraded)	2.40	3.12	3.35	3.67
Total Western Canada	3.64	4.34	4.59	4.93

Table 3. Volume of crude oil exported to the United States by rail.

Year	Volume (barrel)	Volume per day (barrel)
2012	16,963,524	46,475
2013	46,738,300	128,050
2014	58,772,623	161,021
2015	40,626,206	111,305
2016	32,162,711	88,117
2017	47,850,300	131,096

Table 4. All major pipelines regulated by NEB.

Major Canadian Oil and Liquids pipelines:	Domestic Heavy (1000's of barrels per day)	Domestic Light/NGL (1000's of barrels per day)	Foreign Light/Condensate (1000's of barrels per day)	Refined petroleum product (1000's of barrels per day)	Length
Enbridge Mainline	1638.6	384.6	120.7		2306 km (1433 miles)
Enbridge Norman Wells Pipeline		11.06			869 km (540 miles)
Keystone Pipeline	539	24			4708 km (2925 miles)
Trans Mountain Pipeline	12	1989			1150 km (710 miles)
Trans-Northern Pipeline				177.8	850 km (528 miles)
Cochin Pipeline			85.66		3057 km (1,900 miles)

Table 5. Accidents of 2008-2016 of rail transportation and average rate occurrences

Total for the Years 2008-2016	Rail	Pipeline
Occurrences	268	590
Petroleum products transported (Mboe)	1,645.67	15,980
Occurrences per Mboe	0.162	0.037

Table 6. USA and Canada electricity generation by source. Information for Canada is from Natural Resources Canada (https://www.nrcan.gc.ca/energy/facts/electricity/20068), for USA: US Energy Information Administration (https://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states)

Type	USA (2016)	Canada (2015)
Renewables	15.00%	64.80%
Nuclear	20.00%	15.00%
Coal	31.00%	9.60%
Natural Gas and Oil	34.00%	10.60%
Total	100.00%	100.00%
Low-emitting (Renewables and Nuclear)	35.00%	79.80%
Emitting (Coal, Natural Gas and Oil)	65.00%	20.20%

Table 7. Summary of rail data between 2008 and 2016: tonnes transported, mileage of all goods, and reportable occurrences associated with petroleum products. Note: 2007 is not present in this table because it only contains mileage for main-track miles, and not both main-track and yard switching miles.

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Petroleum products (K tonnes)	16,538	16,248	17,886	17,494	22,810	27,901	33,813	30,308	25,543
Petroleum products (Mboe)	121	119	131	128	167	205	248	222	187
Million-Train-Miles (MTM)	90.9	78.4	84.1	85.2	86.1	83.9	86.2	79.3	81.3
Reportable Occurrences	21	21	21	22	27	38	30	26	33
Occurrence per MTM	0.23	0.27	0.25	0.26	0.31	0.45	0.35	0.33	0.41
Occurrence per tonne	1.27	1.29	1.17	1.26	1.18	1.36	0.89	0.86	1.29
Occurrence per Mboe	0.17	0.18	0.16	0.17	0.16	0.19	0.12	0.12	0.18
Petroleum tonnage factor*	0.06	0.07	0.07	0.06	0.08	0.09	0.11	0.10	0.09
Occurrence/Mboe -miles*	0.97	0.96	0.90	0.91	1.08	1.45	1.14	0.92	1.23

* the ratio of petroleum products to the total goods transported by rail

Table 8. Average cost associated for long distance transportation to the society

Type of cost	Pipeline (million-barrels miles)	Rail (million-barrel miles)
Greenhouse Gases	99.73 CAD	200.69 CAD
Air Pollution	347.13 CAD	563.88 CAD
Spills and Occurrences	63.63 CAD	483.87 CAD
Total cost to society	**510.49 CAD**	**1248.44 CAD**

Figure 1. Amount of crude oil and petroleum products transported by rail

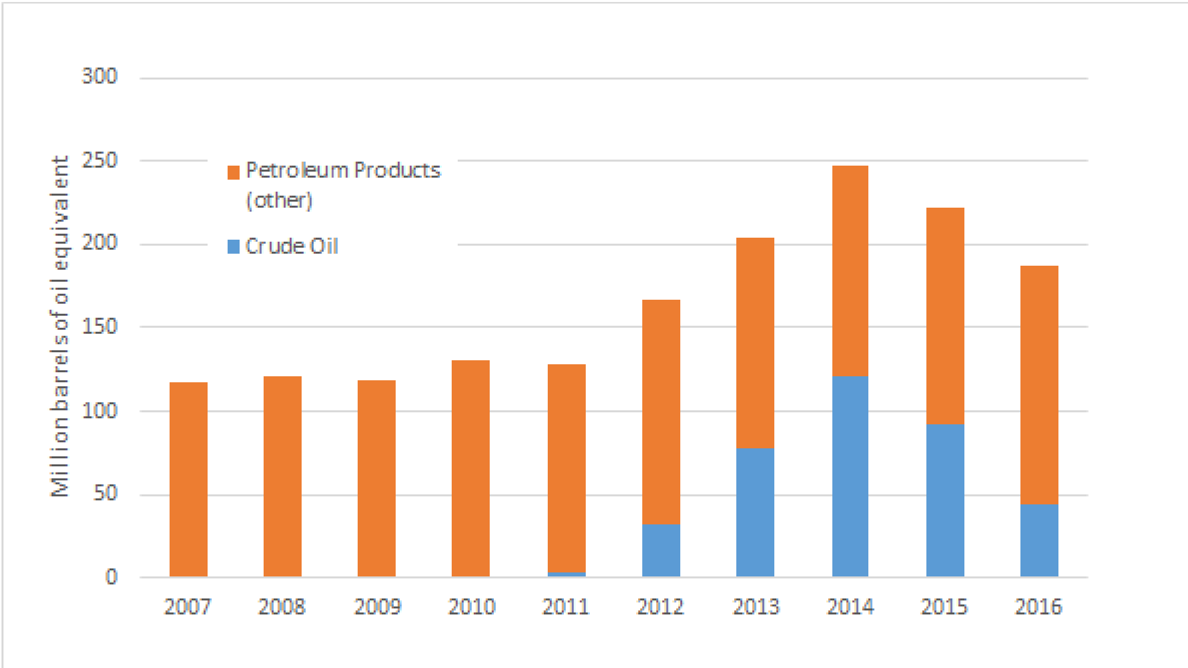


Figure 2. Rail accidents involving petroleum products

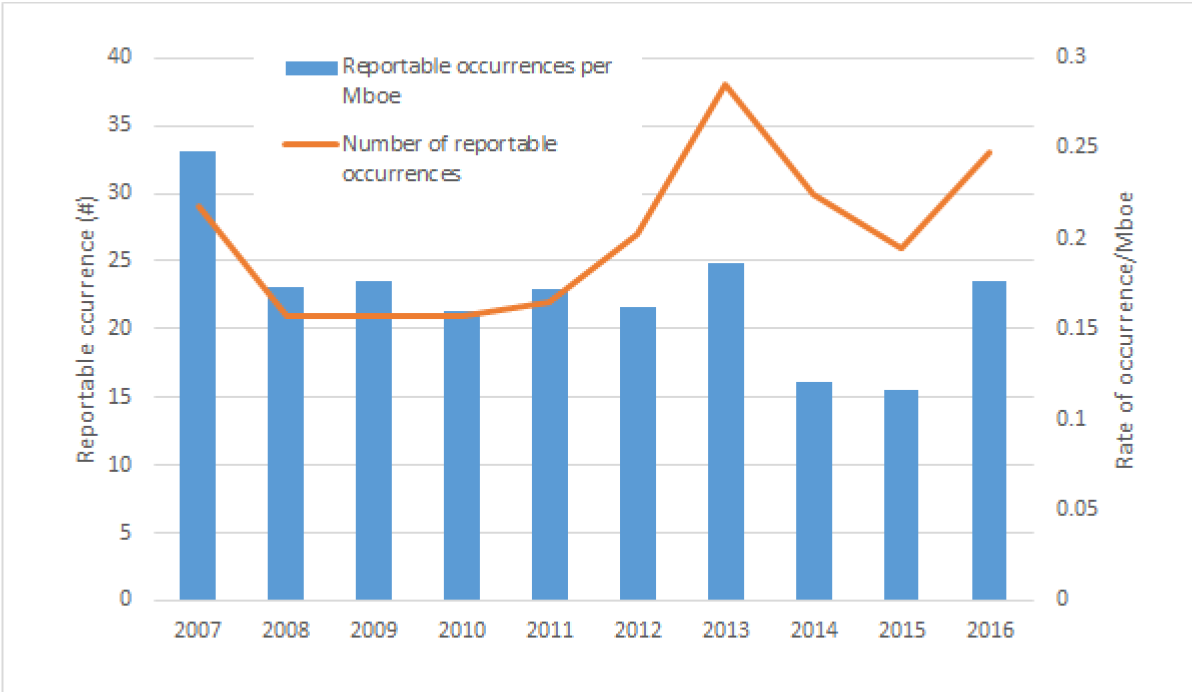
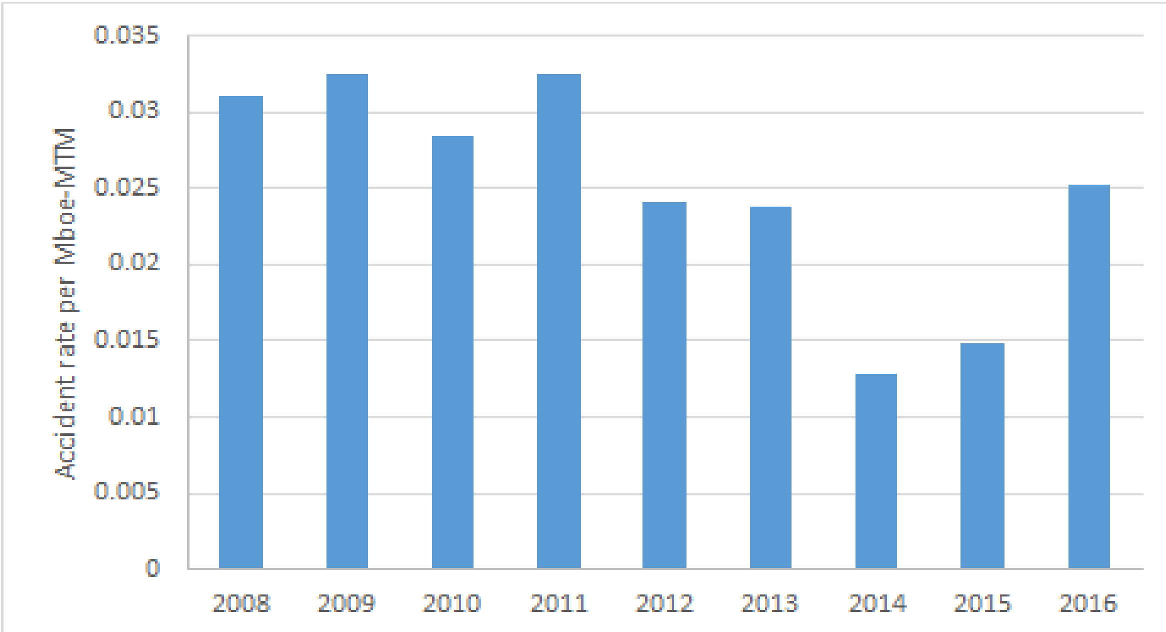


Figure 3. Accident rate per (Mboe-MTM x tonnage factor)



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