Transportation of Oil and Gas

By:

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As the human population expands, it becomes increasingly important to be aware of the consequences that come with meeting our rising standards of living. In today's busy world, it can be easy to overlook the impact that having our needs met right away can have on the environment and the diverse species that live within it. One particularly significant area of concern is the movement of oil and gas. This topic deserves increased attention, especially as the planet's resources become more limited and areas grow more densely populated. As the earth's abundance of oil gets increasingly scarce, it is crucial to explore the safety and efficiency of the various ways it is transported great distances. It has never been more imperative to critically weigh the costs and benefits of each method as they relate to the economy, environment, and regard for human safety and respect. This paper intends to thoroughly investigate the varying modes of oil transportation such as rail, trucking, pipelines, and tankers before recommending appropriate avenues to pursue in the future.

Rail

It is noted that about 97% of Canada's oil gets exported to the United States (U.S.) and 3% goes to Europe and Asia (NRC, 2019). There are various modes of transporting this oil, but rail remains a popular option as exceeding amounts of oil is needed. Furthermore, there are advantages and disadvantages of using this method in terms of efficiency and cost, spill risks, and greenhouse gas emissions.

In regard to efficiency and cost, rail transport remains very ideal. Rail tends to have small fixed costs and short construction periods, which is helpful when needing to transport oil quickly to shorter distances (M, 2019). There is a high demand for oil in new areas where pipelines, tankers, and trucks have various constraints; thus, rail has become a desired method for transportation. Conveniently, one railcar can carry 700 barrels of oil (111,000 liters), which is equivalent to over 3 times the amount of a single truck (Conca, 2018). Additionally, rail allows for faster travel time compared to pipelines and also for quick adjustments to delivery locations as demands shift. However, rail transport may get crowded and delivery times may become slower as other trade markets are en route too, including the agricultural industry. Rail congestion has been highlighted in the legislature as Transport Canada and Agriculture issued an Order in Council to rail corporations to increase transport of grains and given fines otherwise

(Cairns, 2015). Transporting crude oil by rail from Alberta to the U.S. costs about $15 USD per barrel which is three times the cost of a pipeline (Frittelli *et al*, 2014). As Canada is becoming more dependent on U.S. markets, the cost for Canadian heavy crude is getting lower and the gap between U.S. crude and Canadian crude is getting wider (Aliakbari & Stedman, 2019). While this cost may still be high compared to other modes of transportation, rail transport provides advantages. For example, the heated trains improve the viscosity of crude oil sands; therefore, less diluent is added (Frittelli *et al*, 2014). Moreover, railroads are accepting shorter-term contracts with shippers, resulting in more flexibility in the market (Frittelli *et al*, 2014).

The risk of accidents is a huge concern for transporting oil by rail, and oil spills are extremely dangerous because they negatively impact the surrounding environment. Land can be destroyed but can almost never be fully restored, the dynamics of living organisms that inhabit the area are altered, and the pollution from the spills can affect drinking water which ultimately impacts human health (de Santiago-Martín, 2015). It was determined that oil spills are 4.5 times more likely by rail than by pipeline (Green & Jackson, 2015). There have been various unfortunate events where large oil spills have occurred due to railcars. More specifically, the Lac-Mégantic rail disaster is one of the most recent and also one of the worst oil spills, destroying the whole town of Lac-Mégantic in Quebec on July 6th, 2013 (de Santiago-Martín, 2015). The 72-tanker train hauled more than 6 million liters of crude oil, which spilled over land and 100,000 liters made its way into the Chaudière River as the train burst into flames (Page, 2018). Unfortunately, there were forty-seven fatalities and thirty-one hectares of land was destroyed (Page, 2018). Three main areas were affected from this disaster including the Chaudière River, Lake Mégantic, and Lac-Mégantic City. The Chaudière River and Lake Mégantic were connected to the city's water network, resulting in a great burden to the population. The Ministry of Public Health was consequently forced to tell various municipalities to find other sources of water until the fall (Page, 2018). Additionally, the spill affected the benthic community as oil contaminated the water and pushed them onto the bottom of sediments (Page, 2018). The hydrocarbons trapped in sediments affected the growth of microbial density and hindered the photosynthesis of phytoplankton (de Santiago-Martín, 2015). Moreover, fish abnormalities were observed due to fin erosion and it was found that mercury, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and other harmful

compounds resided in their tissues (de Santiago-Martín, 2015). As species decline, the effects are ultimately witnessed amongst food chains and people's sources of nutrition are eventually impacted.

In regard to cleanup, many measures have been taken to restore and remediate the damage. In 2013, greater than forty kilometers of water was cleaned by flushing and manual removal of sediments, vegetation, and rocks (de Santiago-Martín, 2015). Around 25 companies contributed to donating 450 million dollars to the victims and to the companies in which the oil was going to (Valiante, 2019). Over 150 million dollars is currently being used for cleanup and rebuilding the town and it is predicted the reconstruction and decontamination process will take many more years (Murphy, 2019).

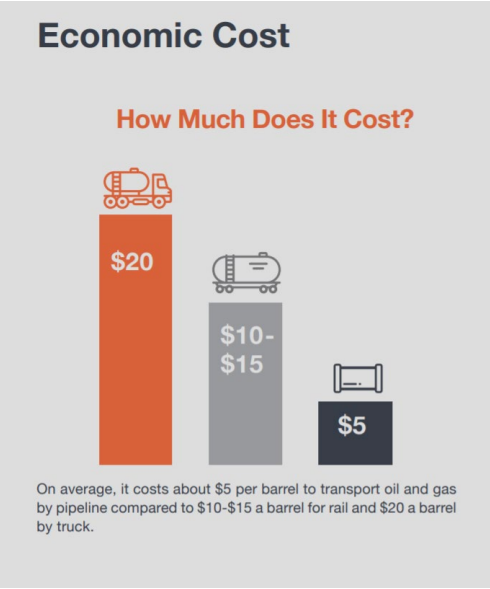
Trains also elicit greenhouse gases that pollute the atmosphere and contribute to climate change. When hydrocarbons are burned, they release greenhouse gases such as methane, nitrous oxide, carbon dioxide, and ozone (Capp, 2019). However, trains are up to nine times more energy efficient than trucks (CESAR, 2017). Trains run on petroleum, more specifically diesel, which emits more carbon dioxide per unit of energy. However, since they are energy efficient, the overall emissions are less compared to trucks. It is important to note that trains emit about 75% less greenhouse gases compared to trucks and about 70% more compared to pipelines (Canada Action, n.d.). Alternative options in reducing the gas emissions include incorporating biofuels as they are produced from recycled vegetable oils or starch and sugar plants (chapman, 2007). Moreover, electric trains are another option to reduce carbon dioxide emission; however, they need proper infrastructure (Chapman, 2007).

Trucks

Currently, the transportation of oil and gas by tanker truck is an essential step in the distribution process worldwide. A single tanker truck will often carry as much as 34,000 liters of product or approximately 200 barrels of oil (Conca, 2014). In Canada, the vast majority (91%) of our oil sent to the US is exported by pipeline, with trucking accounting for just 1% of total distribution in 2016 (American Geosciences, 2019). With this being said, recent pipeline and rail delays have led to an increased reliance on tanker trucks to fill in gaps in transport.

The benefits of transporting oil and gas products by truck are due in part to its availability and flexibility. A tanker truck's only restriction on place of transport is the presence of a road allowing for oil and gas to be distributed to diverse locations. As the cost and risk of transport by truck are high, the tanker truck is in its element for transportation over short distances. This is usually done at the last step of the distribution process, such as transporting refined product from a plant to the customer (Wikipedia, n.d.). As fueling stations have a limited capacity for storage and are often located far from train tracks, the tanker truck provides a very necessary service for the industry. In addition to final distribution, tanker trucks are often used to support the transport of crude oil when there are pipeline and rail delays and deficiencies. According to the Fraser Institute (2018), August of 2018 saw 230,000 barrels of crude transported over long distances by tanker truck. They also report that the number remained at over 100,000 barrels every month in that year. This increased reliance on transportation by truck is concerning when considering some of the potential negative outcomes associated with this method of distribution.

In terms of energy expenditure, transporting oil and gas via tanker truck is the least efficient method over land. In fact, it takes three times the energy for a tanker than it would for a train to move the same amount of oil (American Geosciences, 2019). This is less of an issue when covering short distances, however, there is an increasingly diminished energy return over greater spans. This is likely a factor when one considers the staggering financial cost of using this method of distribution. Indeed, the approximated cost of moving a barrel of oil via truck is approximately $20 USD, a far cry from that of the $5 USD price tag to transport a barrel via pipeline (Green, 2018). This is hardly ideal when one considers the soaring prices consumers face at the pump. Another important variable to look at when comparing these transportation methods is the safety records.



https://www.strata.org/pdf/2017/pipelines.pdf

Figure 1. Comparison of the cost associated with trucking, rail, and pipelines (Hansen, 2017)

Safety records can be broken down into two categories; one representing the loss of human life on the job, and the other representing the amount of oil released in these unfortunate incidents. In terms of human fatalities, trucking oil and gas leads the pack with an average of 10.2 deaths per year in the US (Green, 2018). This is relatively higher than that of trains at 2.4 mean fatalities per year and 1.7 mean fatalities per year for pipelines. These numbers are fairly significant when one considers the cost of a human life. The data is also increasingly damning when one investigates the rate at which oil is being spilled via truck. Trucking is accountable for 326 barrels spilled per million tons moved per mile while pipeline is responsible for 269 and rail accountable for 83 (Green, 2018). While a tanker truck may not immediately release the same amount of oil as its counterparts, the environmental impacts of these incidents can be severe.

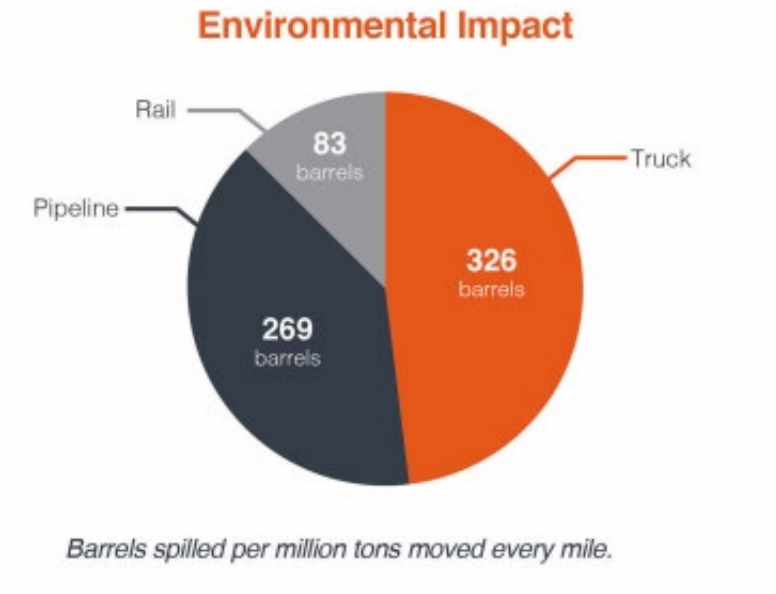


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Figure 2. Statistics of the relative quantity of spilled oil between different transportation methods (Hansen, 2017).

One such case occurred in Kootenays in the summer of 2013 (Lindsay, 2018). According to reports, a tanker truck carrying 35,000 liters of jet fuel slid off of a gravel road and spilled its contents into the lemon creek watershed (Lindsay, 2018). The aftermath of this incident led to mass evacuations downstream of the event, as well as damage and death to aquatic wildlife and damage to farmer's crops. Inhabitants of the area reported getting sick when exposed to the jet fuel and some even launched a lawsuit against the provincial government. The incident was quoted at costing over 4 million Canadian dollars to deal with. Due to the nature of spilling into a moving water way, only 2,150 liters of jet fuel were recovered and approximately 1,600 metric tons of soil had to be removed from the site (Feldberg *et al.,* 2013).

In summary, trucking, while currently being an absolutely crucial step in the process of transporting oil and gas, is probably the most harmful of all of the available resources. It ranks highest in terms of economic loss, environmental spill history, and danger to human life. With the delay of pipelines being built, it is difficult to imagine any decline in its use in the near future.

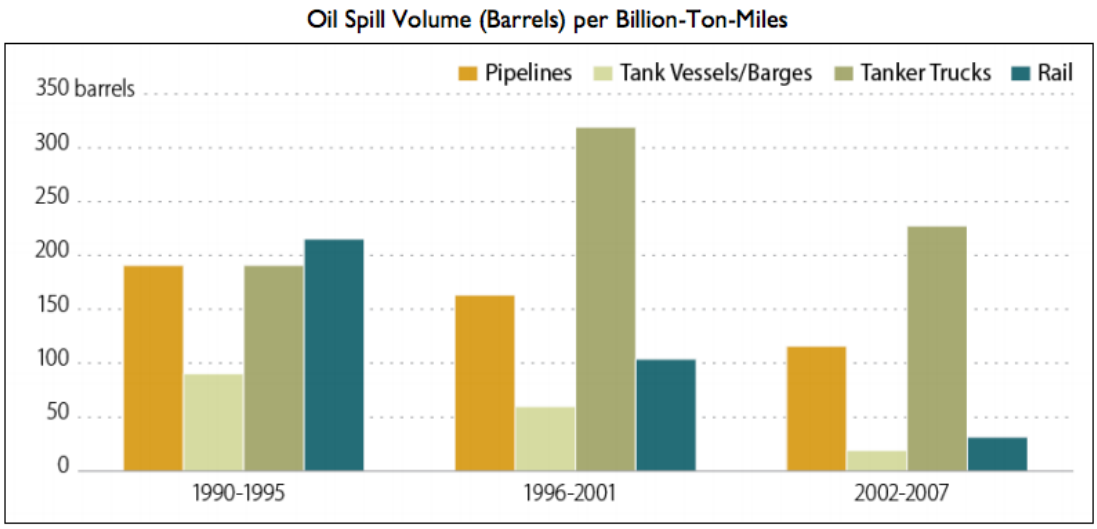

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Figure 3. Oil spills from the various modes of transportation (Frittelli *et al.,* 2014).

Pipelines

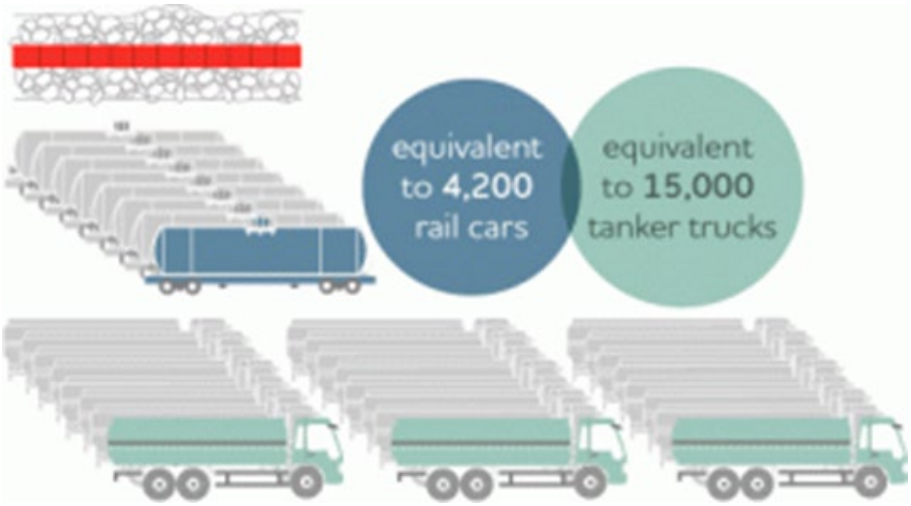
Back in the 1800's when pipelines were yet to be discovered, 80% of the world's petroleum was supplied by Pennsylvania oil fields (Pipeline 101, 2016). The transportation of oil from oil fields to rail was done through teamsters with converted whiskey barrels and horses. The charge for each barrel increased with the increase in demand by the users. In order to overcome the high charges, pipelines were laid from one town to another and were relatively basic and short in 1879. Later, in the early 1900's when kerosene lamp oil shifted to gasoline, pipelines began to be built across the country.

Pipelines are used for domestic, commercial, and industrial transportations. They are divided into two main categories to transport energy products for industrial purposes (DXP, 2019). The first category is petroleum pipelines which include crude oil lines, Carbon dioxide lines, refined product lines, and highly volatile liquid lines. Natural gas liquids are also transported from production wells to refineries. Refined products are then transported to distribution stations or storage places (FracTracker Alliance, 2018). The other category is natural gas pipelines, which collect the raw material from gas wells and transport them to distribution systems across different towns and cities. The distribution system then transfers the processed product to individual households (FracTracker Alliance, 2018).

The major upside of pipelines is that unlike other means of transportation like rails, trucks, and tankers, it does not leave carbon traces in the atmosphere that could result in poor air quality, ozone depletion, and acid rain. They are mostly sealed, therefore reducing impact on wildlife. The sealed nature also causes less spills of highly volatile liquids, which greatly reduces the risk of explosion during transport. This makes it significantly safer for wildlife and people (DXP, 2019). Pipelines require minimal area above ground as compared to other ways of movement. This is because most pipelines are buried under the surface of the earth, except in places with natural rock formations. Moreover, pipelines navigate through less densely populated areas of people, making the consequences of accidents far less disastrous for the affected areas (DXP, 2019).

Every new system has some drawbacks. Although Pipelines are convenient and appear to be better options compared to other means of transportations, there are issues to be concerned about like spills and employment. The TransCanada pipeline that transports oil to the U.S. Midwest has experienced 14 spills, with the latest spill at North Dakota pipeline pumping station in May 2011 (Pipeline 101, 2016). A campaigner with Greenpeace Canada considers this as an act of aggression towards plants, wildlife and people who live in the path of pipelines. Moreover, the leakage of gas through pipelines could lead to combustion or outspread of toxic gases. Furthermore, the rate of employment will fall down once the pipelines are constructed as construction jobs are temporary compared to other means of transportations (Minicucci, 2011).

Nevertheless, pipelines of 110,000 kilometers can fill up to 15,000 tanker truckloads or 4,200 rail cars (CEPA, 2012). This ensures quantitative efficiency and uninterrupted movement of energy products at a lesser cost for domestic and international users. Crude oil and Petroleum reach their destination 99.999 percent of the time as stated in the statistics by NR Canada (Green & Jackson, 2015). They also save us from extreme fuel usage and reduce cost per transportation and emission of harmful gases from thousands of automobiles.



https://www.aboutpipelines.com/en/blog/oil-and-gas-on-the-move-its-what-pipelines-do-best/

Figure 4. Comparing the amount of oil a single pipeline can hold to tanker trucks and railcars (CEPA, 2016).

Trans Mountain Pipeline Controversy

Recently, there has been a significant amount of debate over whether or not the Kinder Morgan Trans Mountain pipeline is the safest or most efficient way to transport oil across Canada. This controversial pipeline is intended to transport crude oil from Edmonton to Burnaby via the coast of British Columbia. Numerous opponents of the Trans Mountain pipeline have voiced a variety of reasons to halt the advancement of the pipeline. They claim that if Canada goes along with the plan to develop a pipeline benefitting high-emitting industries, Canada will not be able to reach its emissions target that was stated in the 2030 Paris Agreement. In this agreement, Canada has promised to decrease its greenhouse gas emissions from 722 megatons to 517 megatons.

Furthermore, opponents of the pipeline worry that it will threaten the local ecosystems throughout the provinces in which the pipeline is to be built. Since the mining of oilsands requires an open pit of land, workers are forced to remove “earth’s most efficient land-based carbon capture system”, also known as the boreal forest (National Observer, 2018). Although oilsands workers assert that the land will be reclaimed once they are done with it, it is nearly impossible for new boreal forest to resurface when left with such toxic soil. Additionally, with

more tanker traffic using the Burrard Inlet route, there is a higher risk of oil spills, including diluted bitumen, dilbit. This can have serious consequences; impacting highly populated areas and potentially pushing the BC Orca whale population to extinction. Even more concerning, there is not enough evidence to tell us whether or not this oil can be cleaned up. The problem with bitumen and dilbit is its processing. Bitumen requires an extremely large amount of water and energy to process and often contains explosive and flammable neurotoxins and carcinogens. As for the Indigenous population of BC, they are mainly concerned with the possibility that building the pipeline may violate indigenous land rights as many proposals map the pipeline through or near their territory. As many as 210,000 indigenous people have voted no to the pipeline due to concerns regarding polluted air, water and land, which could put their lives severely at risk.

Undoubtedly, one of the biggest concerns over the Trans Mountain pipeline is the possibility of a spill. Considering the pipeline will contain dilbit, consequences of any amount or type of spill could be extremely dangerous. Land contaminated by a toxic substance such as dilbit has the ability to impact large portions of the population. For example, Canadians could potentially lose their homes due to the toxic fumes emanating from a spill making previously inhabited lands unlivable. Although pipeline spills are not frequent, it is still a major concern since accidents do happen.

Oil Tankers

Oil tankers are used as a means of transporting large quantities of oil internationally across oceans and waterways. Generally, there are two basic types of tankers and these are categorized by the product that they carry. First, they may transport raw, crude oil via crude tankers with the intention of bringing it to other destinations where it can be refined and processed into fuel and other products. Alternatively, product tankers carry refined oil (usually in much smaller quantities) onto potential markets to be consumed or sold (Wikipedia, n.d.).

As the oil industry grows, international demand increases and transportation by tanker becomes more and more popular. The first oil tanker was commissioned in the 1800’s. Jump ahead to present day and it is currently estimated that 60% of the world's oil is transported by marine tanker (ClearSeas, 2019). Oil tankers provide corporations with an efficient and relatively

inexpensive way to transport their product internationally over long distances. However, this method of transportation does not come without a potentially devastating cost. Oil spills, although infrequent, are capable of causing significant environmental impacts for decades to come (Parker, 2009).

Oil spills in marine ecosystems have the capacity to cause a greater degree of damage than in terrestrial environments due to the challenge of containment. This is because the spread of oil occurs much more rapidly in liquid, skimming out on the surface of water. If oil spills are relatively small, containment can be achieved rather quickly with booms due to the fact that the oil will sit on the surface rather than mix in. Dispersants can also be used to break up crude oil into individual droplets which then sinks to the bottom. Although this prevents the surface spread of the oil, these dispersed droplets are roughly the same size as nutritive particles that are taken up by benthic invertebrates. The toxins in these chemicals become more concentrated as they move up the food chain, and the associated physiological effects they carry can become compounded through a process known as biomagnification (Science Learning Hub, 2012).

The greater issue here is the sheer quantity of petroleum that is often released in oil spills associated with tankers. The largest tankers in this industry can carry up to 4 million barrels of oil (Clear Seas, 2019). Spills coming from tankers this large are much harder to contain and will very quickly become unmanageable due to many cases occurring in remote areas, far away from potential help. Since oil sits on the surface of water, it has the potential to become very widespread, coating coastal ecosystems and interfering with species interactions and food webs. The Exxon Valdez oil spill in Alaska on March 24, 1989 poured an estimated 10.8 million US gallons of crude oil into Prince William Sound over the course of several days. The impacts were compounded by the fact that it took place in a remote location, impeding the response time of rescue efforts from the government and other industry vessels. It is the second largest oil spill in US waters in terms of volume released and it negatively impacted over 2100 km of coastline. Financial costs totaled over $7 billion, however Exxon paid only $2 billion in clean-up costs and $1.8 billion in habitat restoration (History, 2018). Its effects are still being felt in the surrounding ecosystems today.

Oil has a particular ability to disrupt the crucial relationship many animals have with natural oils that are required for insulation from cold and water. This is especially true for sea otters, who rely on the oil in their thick fur to form an insulating layer to protect themselves from the cold, and for sea birds who use oil to preen into their feathers to increase water resilience. When this delicate balance is disrupted, these animals will die from hypothermia. It is estimated that 2,800 sea otters and 250,000 seabirds died as a direct result of the Exxon Valdez oil spill (Gannon, 2014).

As the global population increases, the consumer's need for oil rises with it, and an increase in incidence of oil spills in marine waters will follow. Although multiple regulations and safer, more durable infrastructure are often put into place following disasters such as the Exxon Valdez, mistakes will still happen and wildlife will be lost. A shift towards renewable energy sources is the only thing that could significantly reduce the risk of marine oil spills and losing further biodiversity.

Future Considerations

Suncor in Alberta is proposing to introduce a fleet of 150 autonomous trucks for hauling, so it is not entirely unjustified to propose a potential fleet of autonomous trucks hauling oil across long distances (Moore, 2020). These AI trucks would be able to drive continuously, only stopping for fuel, and would not be slowed down by human needs such as rest for sleep and food. The future of the oil and gas industry is also moving more towards the use of dirtier sources of oil such as tar sands and oil shale. This is due to the lack of raw oil readily available to obtain, and this amount will only decrease as demand rises and supply dwindles. As a result, more companies are beginning to invest in gas to liquid and other similar technologies of production. They believe this is a worthy investment as it will certainly take time for people to move to a predominantly green source of energy, so for the meantime oil still reigns supreme. This is why it remains important to continue to look at the transportation of oil and gas, how the systems are impacting its surroundings, and how it can be improved.

When looking at the transportation of oil and gas, it is critical to know which modes are most comparable and weigh them against each other to determine what should be invested in for the future. The two most comparable modes of transport would be rail and pipeline. This is due

to the fact that they are both methods of mass transportation across land that is separate from a road system and its accompanying traffic. In a comparison of pipeline and rail, researchers from the University of Calgary and Western University have made a comprehensive assessment of the costs associated with the transportation of petroleum products. The paper compiled estimates on the costs of air pollution, greenhouse gases, and spill and accident costs associated with the long-distance movement of petroleum products. The paper found that the "emission and accident costs of pipelines outperformed rail by close to 2.5:1 in Canadian dollars (510 CAD vs 1248 CAD)" (Vragov *et al.,* 2018). These numbers lean strongly in favour of future investment into pipelines, but the consequences of building new infrastructure must be accounted for. There will be impacts on the surrounding land when creating a new pipeline or railway, and the cost of building these structures is far from cheap. For instance, the new Trans Mountain pipeline estimated cost just rose from $7.4 billion to $12.6 billion.

Oil and gas will undoubtedly be a major fuel and manufacturing resource for the foreseeable future. Therefore, it is important to look into what will be the safest, most efficient, and most cost-effective modes of transportation for future investment. As far as what is currently being proposed for the transportation of oil and gas, pipelines seem to be the most favourable. In Canada, 97% of all petroleum and natural gas products are transported by pipelines (CEPA, 2019). For the future of oil and gas, one should look to the improvement of pipelines and how they can be more efficient, safe, and ecologically friendly. To improve pipelines, it is important to analyze the current relevant concerns. In order to decrease the pollution and increase efficiency, it may be a good idea to upgrade pipelines that are already built as opposed to creating a new one. It would not only decrease cost but would also be less harmful on the surroundings, as it would not be necessary to destroy the environment of new untouched land.

We have described in detail the numerous different methods of transporting oil, including rail, truckers, pipelines, and tankers, as well as promising and sustainable future resources such as renewable energy. It is both necessary and beneficial to carefully examine the consequences and advantages of each choice to minimize economic and public health risks. In an exponentially increasing population, any mistake in the transfer of oil can prove to be more catastrophic than ever before. A spill or leak has the potential to permanently damage both marine and land ecosystems or even pollute the air and water supply necessary to sustain human life. On another

note, consumers of a dwindling resource remain concerned with rising prices and today's fast-paced world cannot afford a disruption in the oil supply. Consequently, the harmless and proficient transportation of oil remains a key public concern that demands mounting attention, care, and creativity. Ultimately, earth's population must continue to be cognizant of the potential risks that accompany the fulfillment of our progressively demanding needs.

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