The Bowman Centre For Sustainable Energy

Electric Vehicle Impact on the Oil Sands

A White Paper About Preparing a Nation for the Future

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Policy Statement

The electrification of transport will fundamentally and permanently change the demand for petroleum fuels. Canada needs a rational transition plan for the Oil and Gas sector to address the opportunities and potential negative impacts of this imminent structural change in hydrocarbon demand.

A detailed, equitable, data-driven, and realistic transition plan recognizes the value of bitumen for non-fuel use and requires the active commercialization of existing and emerging innovations. Transformation of the transportation paradigm is already underway. Visionary leadership to drive technical and social solutions will ensure the provinces and Canada benefit from what is an imminent and disruptive large-scale change.

This White Paper argues that a tipping point will occur early in this decade. Action is required within the current mandates of the Federal and most provincial governments.

Abstract

The Oil Sands face numerous challenges, the most publicly discussed being pipelines, oversupply, and COVID-19. These threats are acute. An increasingly important chronic threat is the electrification of transport, which will exacerbate the current oversupply related challenges. The electrification of transportation is approaching the steep rise part of the 'S' growth curve. This rise will irreversibly transform the oil sector. The timing of that transformation is sooner than we think. The rapid pace of electrification and the level of market penetration is key to understanding its implications. The argument that we will need fossil fuels for decades to come is spurious. Oil-producing provinces, the Federal Government and Canadians need to develop and implement a transition plan. Now! With visionary and assertive leadership, electrification of transport could make Oil Sands bitumen a global crude oil of choice via the Bitumen Beyond Combustion initiative.

Key Words

BBC, bitumen beyond combustion, electrification of transport, Oil Sands, electric vehicles, EVs

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Executive Summary

Canada has an opportunity for nation-building through the development and execution of a rational transition plan for the Oil Sands and other provincial oil resources. This White Paper builds on the observation that a 2 million barrel per day (BPD) imbalance between global crude oil supply and crude oil demand (2014-2015) has a structural impact on the benchmark price of crude oil. The oil price impact is significant enough to threaten the viability of Oil Sands producers and is beyond the control of Canadian governments and the oil industry.

This White Paper argues that electric vehicles (EVs) in service around the world will reach numbers high enough to cause a permanent 2 million BPD crude oil supply-demand imbalance. Further, this paper provides compelling information suggesting this imbalance will occur at or before the middle of this decade. And that imbalance will grow over the next few decades. To take advantage of these changes, action within the mandates of current Canadian governments is required.

The development and implementation of a rational transition plan for the Oil Sands sector is essential, will be nation-building in scope, and is needed now. The transition plan must be in place to redirect the 5% of Canadian GDP contributed by the Oil Sector ***FROM*** fuels ***TO*** alternative uses for the oil resources.

Aspects of a transition plan for the Oil Sands should include:

- Acknowledgement that Canadian government policies regarding hydrocarbon fuel products cannot change global crude oil prices.
- Understand that a small shift to electrified vehicles will permanently reduce oil demand and prices.
- Provide incentives for Canadians to produce and process battery raw materials such as cobalt, lithium, vanadium, and high purity carbon.
- Increased incentives for EV battery manufacturing in Canada, while addressing full product life cycle features including material extraction, battery repurposing, recycling, and component recovery.
- Learning from other governments on how to supply labour to new electrical energy infrastructure as coal for thermal electricity generation is removed from the electricity supply.
- Targeted re-skilling for energy, resource extraction, and manufacturing sector workers. Plan training so that skill sets are available at the time project construction and commissioning occurs.
- Support installation of EV charging stations to attract battery and vehicle manufacturers to Canada.
- As a short-term measure only, support high-grading Oil Sands bitumen leases.
- Increase priority and support for the ***Bitumen Beyond Combustion (BBC)*** initiative. BBC seeks to find new ways to add value to bitumen through non-fuel products. Applications using ready or near ready technology include premium asphalt, adhesives, coatings, chemicals. BBC initiatives will lead to advanced materials from bitumen using Canadian designed technology for 21st-century applications like carbon fibre, vanadium, and others.
- Recognize that transitioning from bitumen as a fuel to bitumen as a materials resource offers producing provinces an opportunity to grow their economies in a decarbonizing world.

Action to develop a detailed and rational transition plan is required now with plan execution starting within the mandates of current Canadian governments.

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1. Introduction

A faction of society is of the view that bitumen should remain in the ground, mainly because of the bitumen to fuels/GHG (greenhouse gas) emissions paradigm. Industry supporters suggest the industry can continue to grow because "we will need gasoline and diesel fuel for decades to come." What if it is not an 'all or nothing' solution? Partial decarbonization of the transport sector presents a serious economic threat to global crude oil markets and the Oil Sands. Compelling real-world signals suggest that threat is imminent.

The lack of pipeline capacity presents a threat to Oil Sands growth. But growth is not a reasonable expectation when the world has an excess supply of conventional and non-conventional crude oil. A drop in global demand, such as we have seen during the COVID-19 pandemic, results in plummeting oil prices. Even a moderate reduction in demand can harm higher-priced producers. Therefore, a frank assessment of the potential impact of electrification of transport is required.

That assessment would need to identify the business risk to the Oil Sands sector and determine what actions are necessary to mitigate and adapt to these threats before they unfold. Even a partial penetration of electric vehicles could severely impact the crude oil supply-demand balance. A surprisingly small disconnect between supply and demand has, as seen in recent years, had a devastating effect on crude oil pricing, and by extension, the value of the Oil Sands.

Alberta and Saskatchewan have reserves of more than 300 billion barrels of bitumen[2]. Of this, about 150 billion barrels are recoverable using existing technology and contemporary economics. After adjusting for quality, the bitumen price over the last few years has been in the vicinity of CAN$50/barrel. That multiplied by 160 billion barrels results in an asset valuation of almost ten trillion dollars. Extracting bitumen from the Oil Sands is not easy; it is labour intense and expensive. When oil prices were in the vicinity of $100/barrel, it was economically beneficial. However, the benefit can quickly turn to loss if the market price of oil is less than the extraction cost. Any threat to a ten trillion-dollar asset needs to be investigated and taken seriously.

In years past, the development of this asset contributed significantly to the western Canadian economy and Canada as a whole, but the world is changing quickly. Most countries around the globe are adopting decarbonization policies, which include, in part, the transition to electrified cars, buses, and trucks. Global economic forces and changes in consumer preference within this decade has resulted in a surplus of crude oil that may jeopardize the value of the Oil Sands resource. Therefore, it is time for the oil-producing provinces and the Federal government to consider the vulnerability of the Oil Sands to electrified transport and take action to sustain the value of the resource as the 21st century unfolds.

[2] Bitumen in this paper refers to a form of heavy oil extracted from Oil Sands resources in Alberta and Saskatchewan.

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2. Crude Oil Fundamentals

a. Bitumen Economics

Although crude oil is considered a commodity, all crude oils are not the same. In the early years of crude oil extraction, the oil had low viscosity (light), low in sulphur (sweet vs. sour), relatively easy to process and with high fuel yields. Products include liquified petroleum gas, naphtha, gasoline, kerosene, furnace oil, jet fuel, diesel fuel, lubricants, bunker fuels for marine, industrial, and institutional uses, along with chemical feedstocks. Consumer prices covered the costs of extraction, shipping, refining, marketing, and distributing while turning a profit for all involved.

Although a commodity, crude oil prices vary because of differences in quality and distance to refineries. Refiners strive to manufacture high-value products while recognizing that some products need to be sold at a loss to allow for the production and sale of more profitable products. Products sometimes sold at a loss include petroleum coke, sulphur, low-quality asphalt cement and others. It is important to understand that refineries must process and sell the entire barrel of crude oil except for the small amount they use internally. Therefore, refiners prefer to buy oil that requires less cost to produce high-value products, have a yield slate that matches the market and minimizes low-value product production.

Bitumen is expensive to refine into fuels. Due to its high pitch content, it requires costly, advanced, and sophisticated conversion equipment to produce the fuel products mentioned above. Bitumen from the Oil Sands is also too heavy, or viscous, to ship via pipelines without dilution. The diluent, typically a gasoline precursor, distorts the diluted bitumen yield slate toward higher than desirable gasoline production. Bitumen also contains high levels of sulphur that must be removed and sold. In turn, GHG emissions are higher than conventional crude oils and on par with other extra heavy sour crude oils. As a result, refiners adjust the cost they are willing to pay for bitumen compared to other benchmark crudes.

This adjustment, or discount, is set according to quality and other structural considerations. The bitumen price discount ranges between $10 to US 20$/barrel. Other market influences can drive this discount up. In 2018 the total discount exceeded US 30$/barrel, which resulted in the Alberta government imposing production curtailments. That action led to reduced supply causing restoration of discounts to levels reflecting structural factors such as shipping costs, sulphur, yield slates, etc.

Couple these quality-related disadvantages with a high extraction cost, and it is easy to see that the price structure is high compared to many alternative crude oil suppliers. This makes bitumen producers more vulnerable to price reductions than many of their competitors.

b. Global Crude Pricing

Crude oil is a global commodity with numerous countries producing and selling oil to markets worldwide. Factors affecting global oil prices include consumer demand, oil quality, reliability of supply, distance, and time to market, shipping costs, along with geopolitical factors. The latter include political instability, local, regional, and national scale armed conflicts and political interference in oil markets. Consortiums, such as the Oil Producing and Exporting Countries (OPEC), adjust production volume to manipulate prices. These factors are beyond the control of individual countries, including superpowers.

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Regardless of the rhetoric, Canadian politicians cannot control global oil prices.

c. Crude Oil Supply

Do you remember the 'peak oil scare' of a decade ago? 'Peak oil' revolved around the notion that we were on the verge of depleting the world's known and extractable reserves of light sweet crude oil. The world was preparing for a scenario where the only remaining hydrocarbon resource was extra heavy crude oils such as Oil Sands bitumen. During this time, Canada and the Oil Sands sector prospered along with Canadian equipment and labour suppliers.

Oil Sands production grew from about one million barrels/day early in this century to more than three million barrels/day by 2020. Some US refiners spent tens of billions of dollars, reconfiguring their refineries to process heavy oil available from western Canada and other extra heavy oil producers, including Venezuela and Mexico.[3] The capacity to process extra-heavy crude oil, such as bitumen, increased around the world, given perceived light oil supply constraints.

Then light sweet crude oil supplies from shale formations became economical.

d. Alternative crude supplies

Up until a few years ago, the USA was importing close to half of its almost 20 million barrel/day crude oil demand. Oil production from shale formations in the early years of the last decade amounted to about 500,000 barrels/day. However, over the last decade, technological advances in horizontal drilling and hydraulic fracture of oil-bearing shale deposits occurred. That led to a dramatic increase in shale oil production. Pre-COVID-19, US shale oil production was between 7 and 8 million barrels/day, making the USA the largest oil producer in the world. Coupled with other domestic crude oil production and on a net basis, the US is close to meeting its crude oil needs.

The US is only one of several countries developing shale oil resources. For example, China's shale oil deposits, although more difficult to exploit, are among the largest in the world[4]. Further, shale oil tends to be light, low in sulphur, high fuel yields and, importantly, contains a small percentage of residue (pitch). Contrast that with bitumen, which is high in sulphur and metals, has distorted yields which are aggravated by diluent (dilbit), and contains between 30-40% residue. Complex and expensive equipment is required to convert residue into fuels. Processing residue also turns between 30% and 40% of the residue into petroleum coke, a low-value product.

[3]. It is notable that Canadian refiners chose not to invest in heavy oil conversion units. The result, most Canadian refineries cannot process significant amounts of bitumen. Most eastern Canadian refineries are limited to a small fraction of bitumen in their total crude diet. Given deep discounts, Canadian refineries typically process as much bitumen as they can limited by their refinery configuration. They cannot process more even if new pipeline or rail capacity made the supply available.

[4] **Oil Shale in China,** https://en.wikipedia.org/wiki/Oil_shale_in_China#:~:text=Oil%20shale%20in%20China%20is%20an%20important%20source,equal%20to%2048%20billion%20tonnes%20of%20shale%20oil., Accessed May 9th, 2020

In other words, bitumen, whether diluted or undiluted, is a low-quality crude oil with a relatively high production cost and long-distance to market. Therefore, bitumen is discounted, making the Oil Sands producers more vulnerable to protracted price reductions than many competitors.

Absorbing economic losses due to short term price volatility is possible only if the long-term average price is above the break-even cost.

e. Factors Affecting Crude Oil Supply and Demand

Many factors impact both the demand and the supply of oil products. As in any commodity, if there is a shortfall in supply, then prices will rise. Rising prices will attract new producers, which translates into more supply, pushing prices back down. A supply-demand balance tends to stabilize prices.

Most of the demand for crude oil takes the form of hydrocarbon fuels. A relatively small but growing use for crude oil is in the chemicals sector, particularly plastics. However, if the growth in demand for chemicals is lower than a decrease in demand for fuels, the impact is a market imbalance. An imbalance can occur even if demand and supply are both growing but at different rates. So, although analysts may project growth in demand and supply over the next few years, it does not necessarily mean rising prices.

f. Impact of a Supply / Demand Disconnect

Shale oil, conventional and some unconventional producers can reduce or increase their production to respond to a market supply-demand imbalance. Other producers, such as mega-projects are less agile. It is difficult and expensive to shut down an Oil Sands operation to follow market trends as there is inertia built into the system. Add in geopolitical influences and black swan[5] events, and we have a recipe for volatility and long term disconnects. Other long-term factors expected to impact the balance include:

- Legislated auto efficiency rules, e.g. CAFE Rules, and the resulting impact on fuel demands
- Electrification, or partial electrification, of the transport sector and the pace of electrification
- Demographics and changes in transportation preferences
- Government interventions
    - banning the sale of new fossil-fueled vehicles
    - cartels altering oil production rates to impact prices
    - incentivizing consumers to shift behaviour to reduce consumption

These factors operate interactively and may lead to a protracted disconnect between supply and demand. The question remains, how sensitive is the price to changes in these factors. Does it take a substantial change to cause a minor price impact, or can a small change disproportionately drive a severe price change?

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[5] THE BLACK SWAN: THE IMPACT OF THE HIGHLY IMPROBABLE, Nassim Nicholas Taleb, Black swan events are an unpredictable, outside the realm of the expected and lead to severe consequences.

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3. Crude Oil Economics Realities

The theory and practice of economics are grounded in concepts of supply and demand in a marketplace. The agreed exchange of a product or service for a specific amount of money then becomes the market price at the time of the trade.

Crude oil, including all different grades and qualities, is a commodity. Oil has dominated the industrial age, so much so that the market has settled on several benchmarks. These benchmarks include WTI (West Texas Intermediate), Brent (North Sea oil), and WCS (Western Canada Select).

There are two points to keep in mind regarding these benchmarks and crude oil as a commodity. First, both currently and historically, a given benchmark price reflects the final value of crude oil as a fuel. Second, understanding the wealth of information about each crude oil and the operations of suppliers and consumers, one can compare the benchmark price with the underlying cost of production. The cost of production includes costs of extraction, transportation, refining, royalties, and profit.

Economists sometimes use simplifications to make a specific point. The following two charts are simple visualizations illustrating the impact of structural changes in supply and demand.

First, if there is a group of suppliers that can influence the market (such as OPEC), and they agree to increase supply, there will be a decrease in the price. The supply curve shifts to the right, representing a new supply condition (Figure 1).

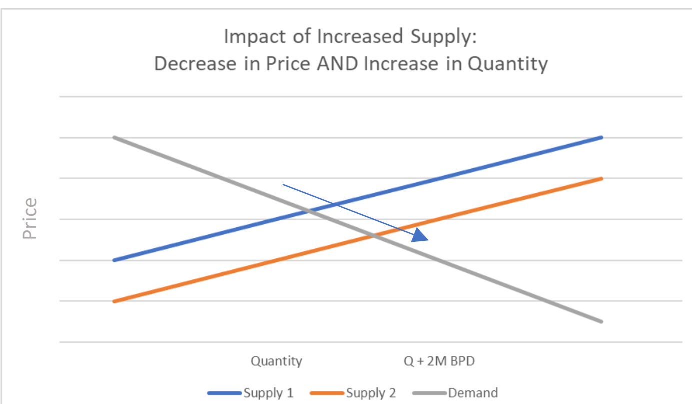

Figure 1 Classic Supply Demand Curve

This is what happened in 2014. Saudi Arabia decided to increase crude oil production. The resulting increase in global oil supply led to a short-term price drop of about 70%, and a longer-term price drop of about 50% since 2014.

The lesson is that a structural change in supply by a non-Canadian supplier profoundly changed the market for all crude oil benchmark prices around the world. Neither a Canadian supplier nor Canadian government policy can have this impact. Nor can they undo the impact.

Figure 2 shows the impact of a structural change in demand. If consumers purchase an alternative energy source for fuel, demand will drop. Suppliers must meet that lower demand or try to stimulate demand by lowering the price. So, the demand curve shifts to the left.

This shift in the demand curve explains the current situation concerning the electrification of transportation. As more vehicles use electricity, the demand for crude oil as fuel will shift to the left.

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A unique event is happening in 2020 and is being carefully studied. The world is seeing a simultaneous shift in both the supply curve for crude oil and the demand curve for fuel. Early in 2020, there was a disagreement between Saudi Arabia and Russia about controls on supply to maintain prices. So, Saudi Arabia responded by increasing production and forcing all producers to accept a lower price for their crude oil.

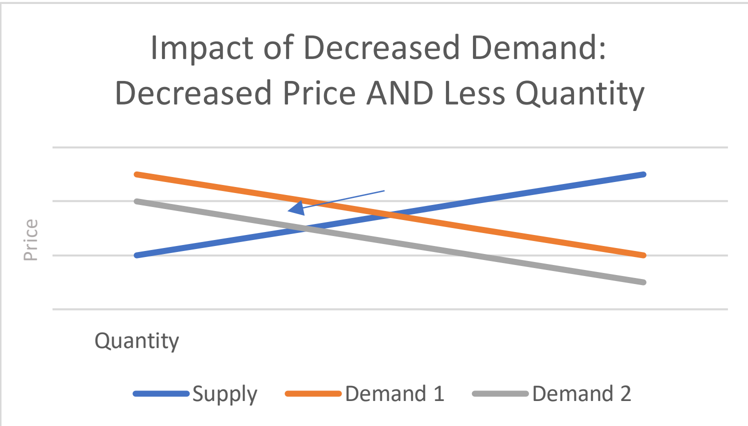

Figure 2 Demand Impact

At the same time, nations around the world took drastic steps to control the spread of the novel coronavirus, COVID-19. As entire economies were locked-down, demand for fuel dropped significantly. At the time of writing (July 2020), the impact of these events remains the subject of study and debate.

For purposes of this White Paper, it is essential to understand that the simplifications of classical economic theory and practice have previously been useful to explain structural changes in crude oil supply and demand. However, an analysis of the compounding impact of even limited transport electrification is required and useful for policymakers.

Classical economic thinking asserts that the adoption of electric vehicles (EV) will cause a drop in demand for transportation fuel. EV adoption would lead to a structural change in demand because it is not easy to switch back-and-forth between electric cars and internal-combustion engine (ICE) vehicles.

With this impending structural change, there will have to be a change in the crude oil supply to satisfy the remaining demand. This realization justifies the development and implementation of a rational transition plan. A plan that guides a paradigm shift ***FROM*** bitumen as a fuel ***TO*** other opportunities to continue capturing the value of this natural resource in a partially electrified transport world. In other words, bitumen beyond combustion, or BBC[6].

[6] Alberta Innovates, https://albertainnovates.ca/focus-areas/clean-resources/bitumen-beyond-combustion-bbc/

4. Electrification of Transport – A Deep Dive

Video 1 GM Add for e-Hummer

“A quiet revolution is coming,” the commercial declares. “All electric, zero emissions, zero limits.” These words are from a General Motors ad aired during the 2020 Superbowl. The add promoted GM’s plans to build and sell a 1,000 horsepower, all-electric Hummer pickup truck to be on the market in 2023. (See Video 1).

This ad is one example of a change already underway in the light-duty vehicle sector. Billions of dollars have been spent[7] on light-duty electric vehicle development with billions more earmarked for this decade. Expenditures intended to cause a transition toward electric vehicles and, eventually, autonomous vehicles.

The latter part of the last decade saw overall light-duty vehicle sales begin to decline, while the sale of EVs enjoyed double-digit growth in most global markets[8], at least up until the COVID-19 pandemic.

Before COVID-19, most vehicle manufacturers were introducing new EV models to the market. Even so, conventional wisdom suggests the transition to EVs will take decades; thus, we should continue developing the Oil Sands sector for fuels and push for increasing market share. Eventually, the industry may need to accommodate a ‘drift’ in reduced fuel demand due to increased EV adoption, but not yet.

However, is the conventional wisdom ‘we will need fossil fuels for decades to come, so let us proceed with growth for fuels demand’ a prudent approach? No one disputes there will be vestigial demand for fossils fuels for decades to come. But does the transition to electrified transportation need to be complete before causing severe and irreversible damage to the Oil Sands sector? The question is, what will the demand decline **rate** look like? If the current supply surplus continues, will oil prices be high enough to maintain the economic viability of one of the world’s most expensive sources of oil?[9] A rational transition plan for the Oil Sands sector will answer these rate questions.

Looking at the low percentage of annual EV sales, plus yearly sales forecasts until 2030, suggests that any threat to the Oil Sands may be many years away. However, is looking at annual EV sales in the context of annual vehicle sales the best indicator of future oil demand?

Annual EV sales figures may be the wrong indicator as all vehicles are not equal. Future oil demand will depend on the number of ICE vehicles in service, their average fuel consumption and their annual distance travelled. Since fuel and operating costs for EVs are approximately one quarter to one-fifth of ICE vehicles, they will appeal to customers with high mileage applications, such as Canada Post, Amazon,

[7] **All the things carmakers say they'll accomplish with their future electric vehicles between now and 2030**, Tim Levin, Business Insider January 28, 2020, https://www.businessinsider.com/promises-carmakers-have-made-about-their-future-electric-vehicles-2020-1– Accessed May 4, 2020

[8] **Combustion engine car sales to hit peak demand in 2018, say analysts**, Patrick McGee, Financial Times, December 2018. https://www.ft.com/content/62506c24-0aae-11e9-9fe8-acdb36967cfc Accessed May 6th, 2020

[9] **Oil price rout: which supply is most at risk of shut-in? Wood Mackenzie,** 27 March 2020 https://www.woodmac.com/press-releases/price_rout_shut_in_supply/

Fed Ex, taxicabs, etc. Large fleet operators have the most to gain from moving to EVs, which have lower refuelling costs and longer service lives due to their simpler drive systems. Fleet vehicles typically travel 5 to 10 times further in a year than personal vehicles.

Annual EV sales may also be misleading if the sector is at the inflection point on a product development 'S' growth curve. Displacing ICE vehicles for EVs permanently removes the demand for oil for that service. Annual sales figures fail to recognize that once a car enters service, it continues to be in service for a decade or more.[10] As new vehicles enter service, older fuel-intensive vehicles are retired. Therefore, it is more informative to look at cumulative EVs in service around the world rather than annual sales. This is the area under the curve, the integral, of a plot of yearly sales starting in 2012.[11] The question that needs asking is: how many EVs would be required to impact the price of crude oil? And when might that occur? Is it *decades* into the future? ***OR*** is it just around the corner? The answer to these questions must be part of a rational transition plan for the Oil Sands and Canada's other oil resources.

a. Change in Crude Oil Demand and Electric Vehicles

As discussed in the section on crude oil pricing, a small change in hydrocarbon fuel demand has a significant impact on oil prices. This impact was made evident from the 2014 and 2015 experience. In 2014, the WTI benchmark oil price was in the vicinity of US100$ per barrel and stable at that price. By 2015, the price varied between $30 and 40 US/barrel with price volatility. What happened?

Geopolitical forces came into play, not that different from what we saw in late 2019 and early 2020, before the COVID-19 impact. But the 2014 event is more revealing in that it was not as severe. In 2014 Saudi Arabia decided to increase production while demand in growth markets, mainly Asia, plateaued. The combination of these two factors led to a global supply-demand imbalance of about 2 million barrels/day.[12] In 2014, the world produced and consumed a little over 90 million barrels per day. Two million barrels per day represents about a 2% imbalance. However, that 2% change resulted in about a 70% drop in oil prices!

Despite the emergence of an oversupply environment, most global oil producers currently hold a similar forecast of future demand, which increases for the next decade or so, before declining later in the century. Producers strive to sell as much oil as possible, and some can overproduce. Overproducing drives the price of oil down and forcing the high-cost producers out of the market to benefit the overproducer. Producers are already competing to sell their product in an oversupply environment, so a rapidly emerging technology disruption will further aggravate the problem by decreasing demand. These factors present a significant and permanent risk to crude oil prices.

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[10] The exception is premature removal from service due to accident or other cause. For purposes of this paper the number of EVs removed from service prematurely have been ignored.

[11] The year 2012 is suggested as that is when Tesla introduced its Model S and when Nissan had established a market for its LEAF. Also, by 2012 the LEAF and the Model S were production scale vehicles vs. custom built vehicles.

[12] **Factors Behind the 2014 Oil Price Decline**, Reinhard Ellwanger, Benjamin Sawatzky and Konrad Zmitrowicz, Bank of Canada Review • Autumn 2017. https://www.bankofcanada.ca/wp-content/uploads/2017/11/boc-review-autumn2017-ellwanger.pdf

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This leads to a question; just how many electric vehicles would need to be in service to cause a permanent 2% disconnect between crude oil supply and demand? Such a disconnect would only impact crude oil prices if the supply remained the same, or worse, if supply increased in the face of reduced demand. But there is another wrinkle; demand could rise, as many predict, for decades to come. If EVs or any other factor causes a decline in the ***rate*** of increased demand compared to increased supply, then crude oil prices will be threatened. The critical point to consider is whether growth in EVs will cause an imbalance between demand and supply regardless of whether the absolute demand and supply grows over the next few decades.

b. How Many EVs Would it Take and When Might That Occur?

It is relatively easy to determine a rough estimate of the number of EVs required to disrupt the market (Appendix 1). Globally, about 40 million EVs across all services would reduce gasoline and diesel fuel demand enough to permanently reduce crude oil demand by about 2 million barrels/day. That number of vehicles becomes much smaller if high mileage fleet vehicles disproportionately convert to EVs. If 40 million EVs could cause a 2 million barrel/day imbalance, the next question is, when might this occur?

Niels Bohr is credited with saying, "It is difficult to make predictions, especially about the future." So, answering the question, "when will we reach 40 million EVs?" is a more complicated question since the answer depends on future sales projections. To arrive at a plausible date, we need to consider two factors. The first is to estimate the number of EVs currently on the road using historical data on actual EV sales. The second involves considering the many scenario-dependent sales projections for future years until we come to 40 million EVs in service.

At the end of 2019, there were 7.2 million EVs in the world,[13] which represents about 20% of the 40 million EV tipping point. How many years will it take to go the rest of the way?

In May 2019, the International Energy Agency (IEA) published its ***Global EV Outlook 2019, Scaling-up the transition to electric mobility***.[14] That report uses two scenarios to project cumulative EVs in service every year until 2030. The first and more conservative (low) *New Policies Scenario* (NPS)[15] is based on existing government programs and policies intended to meet GHG reduction goals. The NPS scenario suggests there will be more than 40 million EVs in service by 2025, and 70 to 80 million in service by 2030. When we add plug-in hybrids to the number of

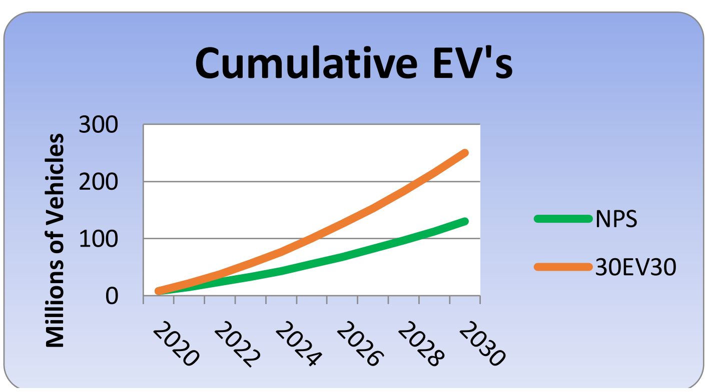

Figure 3 Forecast BEV + Pug in Hybrids for IEA Scenarios

[13] IEA Global EV Outlook 2020 https://www.iea.org/reports/global-ev-outlook-2020

[14] IEA Global EV Outlook 2019 https://www.iea.org/reports/global-ev-outlook-2019

[15] New Policies Scenario (NPS) is described in Chapter 3 of the IEA Global EV Outlook 2019 NPS: *"The scenario incorporates the policies and measures that governments around the world have already put in place, as well as the likely effects of announced polies that are expressed in official targets or plans". Chapter 3 pp 115.*

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EVs, the total electrified vehicles in service by 2025 exceeds 50 million. These vehicles use zero to little crude oil-based fuels.

The IEA's second scenario, EV30@30 (EV30), uses forecasts that are based on the **manufacturer's goals** of achieving a 30% EV market share by 2030. Under this scenario, the cumulative total EVs in service by 2030 would be 250 million. It is interesting to note that by 2040, Bloomberg New Energy Finance[16] says more than half of new cars will be electric.

Figure 3 shows the forecast uptake of EVs based on the two IEA scenarios. Notice that both projections are almost linear, i.e. the number of additional vehicles year over year is essentially constant. This is decidedly unusual, as most forecasts of this type have an elongated S shape, where the curve starts flat but becomes steeper every year until becoming almost vertical before levelling off again. The IEA forecast is also inconsistent with the uptake of EVs before 2020, where numbers nearly doubled year over year.

The IEA chose to use the lower NPS scenario as the "central scenario" of their World Energy Forecast.

This forecast overestimates oil requirements, even if actual EV uptake only meets the moderate 30EV30 scenario. The NPS scenario is so modest that the number of EVs manufactured barely covers the increase in total vehicles forecast for those years. The NPS scenario essentially estimates that the number of ICE vehicles will remain roughly constant over the decade. The two forecasts diverge by so much that if EV uptake follows the moderate NPS forecast, we will have a 2 mmbbl/day (million barrel/day) oil oversupply as early as 2024, and grow to over 6 mmbbl/day oversupply by 2030.

Things become even more extreme if the 50EV30 (50% of new vehicles are EVs by 2030) scenario unfolds, as shown in Figure 4, where the 2mmbbl/day oversupply occurs a year earlier, in 2023, resulting in an oversupply of almost 17 mmbbl/day by 2030.

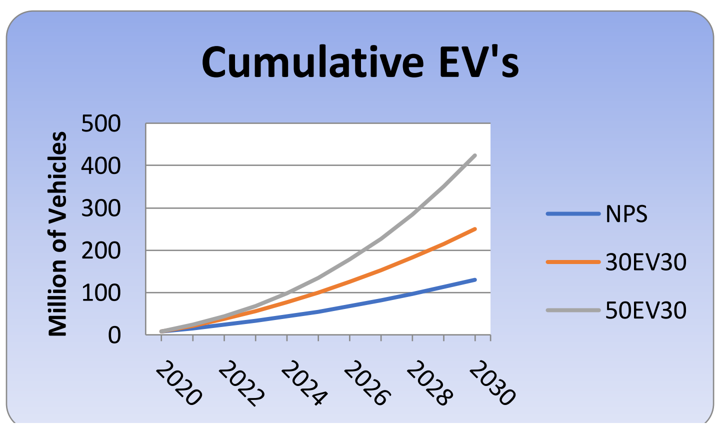

Figure 4 Cumulative EVs with IEA 50% by 2030 Scenario

Both scenarios suffer from the same fault. While governments and manufacturers encourage sales through various price mechanisms to meet their minimum goals, it is consumers who determine what type of new vehicle they buy. Actual EV sales may be higher than either scenario suggests if purchasers perceive EVs to be superior products.

[16] Electric Vehicle Outlook 2020, Bloomberg New Energy Finance, https://bnef.turtl.co/story/evo-2020/page/3/1?teaser=yes

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All this suggests that ***by 2025, less than five years, the number of electrified vehicles could be high enough[17] to cause a permanent oil supply surplus leading to price reductions sufficient to threaten the Oil Sands as a fuel supply resource.***

Are we at risk of being blindsided by these changes? The answer to these questions must be part of a rational transition plan for Canada's Oil Sands and other oil resources.

c. What is driving this change?

Some would like to believe that the growth in global EV sales is due to consumers interested in mitigating GHG emissions. Although that may be true for some people, there is little evidence that environmental concern explains consumers purchasing 7 million electric vehicles.

Initially, EV sales were growing in most countries because of government policies related to climate change initiatives (IEA's NPS scenario). These policies include access to HOV lanes, restrictions on petroleum-fueled vehicles from downtown areas, support for the installation and often free-use of charging stations. However, providing a financial incentive that reduces EV prices to near parity with ICE cars is likely the primary cause. Added to these policy steps is the fact that EVs offer lower fuel and maintenance costs than ICE vehicles. As a result, the total cost of ownership, with subsidies, is currently about the same as the total cost of purchasing and operating a conventional vehicle.[18]

There are also several less-tangible advantages of owning an EV. These include time saved by not having to go to the gas station (recharge at home), get the brakes renewed[19] or visit the dealer for other regularly scheduled maintenance, such as oil changes. Most EVs also tend to outperform their fossil-fueled counterparts for responsiveness, acceleration, noise, and high-tech features.

In addition to these policy measures and advantages offered by EVs, numerous countries and sub-national jurisdictions around the world have announced the year in which they will ban the sale of new petroleum-fueled vehicles. The sales ban year for new ICE vehicles (Appendix 2 and 3) range from 2025 to 2040. These jurisdictions are not planning to eliminate fossil fuel vehicles by their announced dates, just ban the sale of new ICE vehicles. If you already have an ICE vehicle, you can continue to drive it. But these in-service ICE vehicles will be replaced with vehicles that do not use gasoline or diesel fuel.

Whether these ban dates are met or not, the message from leaders of these jurisdictions is clear.

These policy and performance factors are not only incentivizing consumers to select EVs; the messages are being acted on by vehicle and vehicle parts manufacturers.

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17 **More than 37 Million Plug-in Electric Vehicles are Expected to be in Use in 2025**, Guidehouse Inc .Jan 11, 2017, https://guidehouseinsights.com/news-and-views/more-than-37-million-plug-in-electric-vehicles-are-expected-to-be-in-use-in-2025

18 **So you think electric vehicles cost more? A 10-year comparison shows they're actually cheaper**, Stephanie Wallcraft, Toronto Star, June 23, 2020 https://www.thestar.com/business/2020/06/23/so-you-think-electric-vehicles-are-pricier-a-comparison-of-costs-over-ten-years-proves-otherwise.html

19 EVs use regenerative breaking to slow and stop, break life is significantly extended compared to ICE vehicles.

d. Electric Vehicle Investment

Government policies, coupled with consumer response, has led to massive investment by vehicle manufacturers around the world. Almost daily, we see multi-million-dollar investment announcements to support advances in battery, new car, truck, bus, and autonomous vehicle technologies. These investments are not limited to new companies such as Tesla, Rivian, Lordstown-Endurance, Nickola, BYD, Cherry Automotive and many others. Almost all legacy manufacturers have embarked on a nearly irreversible path toward electrifying their fleets.

These global automakers have already invested over $90 billion[20] in electric vehicle development. To secure their position in the transition, these companies have pledged to spend over $200 billion[21] more over the next few years. The objective of this roughly $300 billion commitment is to broadly transform their fleet offering from petroleum-fueled vehicles to electrified vehicles. When talking about private sector investment of this magnitude, it is essential to keep in mind; these are profit-oriented and publicly traded companies.

The leadership teams of these organizations must protect and grow their shareholder investments. They are formally announcing these strategic investments and committing their shareholders' money. Why? Because they think the future of their companies depends on these investments in electrified vehicles.

e. Electric Vehicle Availability

Even though legacy vehicle manufacturers have committed to spend some $300 billion of their shareholders' money on electric vehicle development, the Tesla brand has become synonymous with electric vehicles. But Tesla, and Nissan's Leaf, are no longer the only brands on the market today. (Figure 5)

Most legacy manufacturers now, summer 2020, have at least one battery-electric or plug-in hybrid vehicle on the market. These offerings are mainly in the luxury and sport utility categories and account for most of the more than 7 million EVs currently in service. Further, electrified pick up trucks by several manufacturers are in advanced stages of

Figure 5 Sampling of Currently Available EVs

[20] **Global carmakers to invest at least $90 billion in electric vehicles,** Paul Lienert, Reuters, January 15, 2018 https://www.reuters.com/article/us-autoshow-detroit-electric-idUSKBN1F42NW, Accessed May 4, 2020

[21] **All the things carmakers say they'll accomplish with their future electric vehicles between now and 2030**, Tim Levin, Business Insider January 28, 2020, https://www.businessinsider.com/promises-carmakers-have-made-about-their-future-electric-vehicles-2020-1– Accessed May 4, 2020

development with production scheduled to begin this year or early next year.

The positive reaction by consumers to currently available models is indicative of the likely response to the smorgasbord of new models, including pickup trucks, to be available within a year or two. These new offerings will appeal to the more than 60% of Americans[22] who expressed interest in buying an electric vehicle.

Household consumers are not the only market segment interested in electric or electrified vehicles. Commercial vehicle offerings, notably commuter buses, intra-city trucks and light-duty delivery vehicles, are already on the market. Long vehicle life, low fuel costs and minimal maintenance requirements make these vehicles attractive to businesses. Numerous cities, including those in Canada, have committed to electrifying their bus fleets (Figure 6).

Postal and commercial delivery services are following suit. Also, longer-range intracity tractors and heavy-duty trucks are in the late stages of development, with production planned to begin early in this decade.

Even if COVID-19 leads to a protracted recession, the transition to fully electric and electrified vehicles appears to be inevitable. COVID-19 leads to two questions. How much oil demand is permanently destroyed, and how much delay has the pandemic caused in the EV transition? The answer to this question must be part of a rational transition plan for Canada's Oil Sands and other oil resources.

Figure 6 City Buses

The threat to immediate and permanent declines in oil demand is serious. Perhaps the most critical factor has to do with the primary barrier to EV sales, vehicle purchase price.

f. Price Parity and Overall Cost of Vehicle Ownership?

Historically, electric cars have been significantly more expensive to buy than comparable petroleum-fueled alternatives. This price differential is mainly due to battery costs. Further, the significant reduction in operating and maintenance costs was not enough to make up for the difference in up-front cost, even after government subsidies.

Battery prices, along with drive train and other technological cost reductions, are rapidly reducing the up-front cost disadvantage. This change started with high priced, low volume markets before 2010.

[22] **New survey shows strong support for electric vehicles across economic spectrum**, Consumer Reports, July 2019. https://advocacy.consumerreports.org/press_release/evsurvey2019/ Accessed May 4th, 2020

Electric Vehicle Impact on the Oil Sands

Figure 7 2008 Tesla Roadster

In 2008, Tesla Motors began limited production of its all-electric roadster (Figure 7). That car represented a technological breakthrough in electric vehicles. The roadster was the first car to use lithium-ion batteries, offer a range of almost 400km, accelerate to 100km/hr in 3.7 seconds and achieve a fuel economy equivalent to 2 L/100km. In 2008, the roadster was priced at about $100,000 US, meaning that it competed in price and performance with sports cars like the Porsche 911.

A few later years, Tesla launched its first mass-production vehicle, the Model S (Figure 8).

The Model S sport sedan is a mid-size car introduced in 2012 and still in production today. At product launch, the car was available in the $60-90 thousand US range. Although there were other drive train differences affecting acceleration and top speed, the primary determinant behind the price range was battery size.

Figure 8 Tesla Model S

The Model S competed[23] in price, performance, and styling with the large luxury sedans from Mercedes-Benz, Audi, BMW, and Lexus, and similar vehicles in 2012 (Video 2). As the Model S evolved, it proved successful at competing with higher-end mid-sized luxury cars. During this period, the only commercially available electric vehicle styles included a sports car, a sedan, and a small hatchback (Nissan Leaf). A vital vehicle segment, the sports utility vehicle (SUV), was not represented.

Video 2 Model S Competitors

In 2017, Tesla introduced the Tesla Model X (Figure 9). The Model X is a high-performance SUV competing in price with the Cadillac Escalade, Land Rover Range Rover, Mercedes Benz G Class, and other SUVs priced at over $100 thousand. Although the Model X competes favourably in price, quality size and other features in this category, the Model X, like the Model S, is in a class of its own when considering performance. Due to the characteristics inherent in electric motors, these early Tesla models overwhelm their market competitors. [24] [25] This means that by mid-decade, high-end electric vehicles were commercially available with up-front price points at

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[23] **2012 Tesla Model S review:** *Tesla rethinks the automobile,* Wayne Cunningham Road Show by CNET, Jan. 9, 2013 https://www.cnet.com/roadshow/reviews/2012-tesla-model-s-review/

[24] **2017 Tesla Model X,** Aaron Cole, The Car Connection, June 26, 2017 https://www.thecarconnection.com/overview/tesla_model-x_2017#image=100585094 accessed May 5th, 2020

[25] https://www.thecarconnection.com/car-compare-results/mercedes-benz_g-class_2017-vs-tesla_model-x_2017

or near price parity with comparable gasoline-fueled cars. However, price parity was not true for low-priced vehicles targeting mass-market consumers. Nissan's Leaf, a compact hatchback, is an example of such a car.

Since 2012, the Nissan Leaf has, in some ways, paved the way for low priced vehicles, like the much more expensive Tesla models did for their vehicle category. The Leaf was the first mass-produced and mass-marketed all-electric vehicle featuring a lithium-ion battery and a sticker price in the mid-US 30,000$ range. Although the car did not compare well with its gasoline and diesel counterparts, Nissan sold 450,000 units by December 2019, more than any other electric vehicle. The Leaf's performance has improved with the second-generation Leaf now available for a lower price than the original.


Jorgen Hendriksen on Unsplash

Figure 9 Tesla SUV Model X

The Nissan Leaf faced competition when General Motors released the Chevrolet Bolt in 2017. Both cars competed in the US $35 thousand (pre-subsidy) average price range for new cars in the USA. Although the Bolt offered spirited performance compared to the Leaf and a wide range of high-tech features, the vehicle remained pricey compared to its fossil-fuelled counterparts. By early 2018, the elusive mid $30 thousand US electrified vehicles, which included plug-in hybrids like the Chevrolet Volt, were pricey, even with subsidies. With subsidies, these vehicles sold reasonably well, although manufacturers claimed they lost money with each sale. The market was limited to buyers with low to zero direct emissions high on their decision criteria, until 2018.

Video 3 Model 3 Competitors

In 2018, Tesla launched the long-awaited Model 3. The Model 3 target base price was US 35$ thousand, which was the average new car sales price in the US at the time.[26] The Model 3 would compete with other EVs in this price range, including the Leaf, Bolt, Volt, BMW *i3,* VW e-Golf, Kia Soul EV, and others. But the Model 3 also competed favourably, and in many ways, proved to be superior to its gasoline-fueled competitors (Video 3).

Figure 10 illustrates a trend in purchase price parity, as revealed by this EV history. Price parity was achieved for expensive vehicles (~100k$) early in the last decade. By the end of that decade, price parity dropped to mid-range (~35k$ US) priced vehicles.

[26] Although they came close, they did not meet that target.

Electric Vehicle Impact on the Oil Sands

By the end of 2019, Audi, Fiat, GM, Ford, Hyundai, Jaguar, Kia, Mercedes Benz, Porsche, Tesla, Volvo, VW, along with several Chinese companies were selling production EVs. When you consider the purchase price, performance, finish quality and high-tech features, many of these vehicles, particularly the more expensive versions, are at or near price parity without subsidies. The only market segment not represented in the near or at price parity spectrum is the less than $20 thousand US market. Falling battery prices coupled with economies of scale suggest that most electric vehicle offerings will enjoy price parity with their ICE counterparts by the middle of this decade.[27]

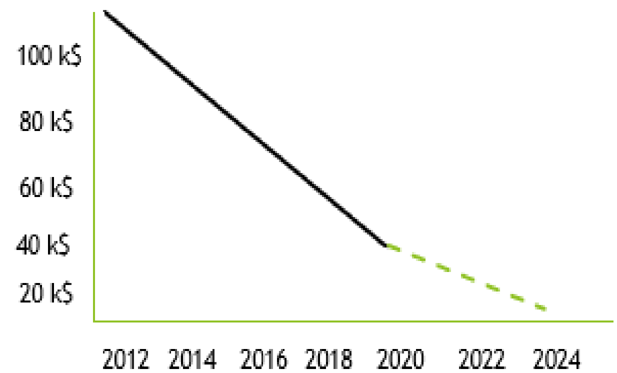

Figure 10 Purchase Price Parity

The middle of this decade keeps appearing as the timing for a meaningful number of EVs in service.

On April 25, 2020, during the COVID-19 pandemic, Ken Morris, GM's Vice President for Electric and Autonomous Vehicles said, "*My hope and gut feel is that there's going to be an inflection point in the mid-2020s where suddenly people are going to be buying [EVs] at a faster rate than anybody expects, just because the driving experience on these vehicles is fantastic*." Mr. Morris added, "*When you get used to charging your vehicle, like a phone at night, and you don't worry about it, you never have to stop at a gas station. There's a lot to be said for that kind of a lifestyle.*"[28]

g. Electric Vehicle Charging Options

(Joenomias) Menno de Jong from Pixabay

Figure 11 Public Level 2 Charging Station

A common concern inhibiting prospective buyers from purchasing an EV involves the question of charging, especially for those people living in apartment buildings or only having access to on-street parking. A perceived lack of charging stations, the time required to recharge, and limited range leads some people to conclude that EVs are impractical.

Let us start our discussion about charging by describing the currently available charging options. Today's EV owners have access to three levels of charging technology: Level 1, Level 2, and Level 3.

A Level 1 charger uses a typical North American household 120V AC circuit. This level of charger is practical for electric motorcycles, plug-in hybrid vehicles, or vehicles with batteries of notionally 20 kW-hrs or less. Assuming a 20-kWh battery and 10 cents/kWh, it would cost $2 to charge. Cars with

[27] **Electric Car Price Tag Shrinks Along With Battery Cost**, Nathaniel Bullard, Bloomberg, April 12, 2019, https://www.bloomberg.com/opinion/articles/2019-04-12/electric-vehicle-battery-shrinks-and-so-does-the-total-cost

[28] https://www.automobilemag.com/news/electric-vehicles-will-soon-dominate-general-motors-product-lineup/ interview with Todd Lassa, Automobile Magazine, April 25th 2020. Accessed May 6th 2020.

batteries of that capacity can be charged with a Level 1 at home overnight. However, a Level 1 charger becomes impractical as battery capacity increases.

EVs with a range of 300 km or more, will be equipped with larger batteries. This type of vehicle requires a Level 2 charger to charge overnight. Level 2 chargers use 220 V AC circuitry typical of a household electric stove or dryer outlet. EV owners with access to private parking usually install this type of circuit adjacent to where they park their car for overnight charging. A full charge for a 50kW-h battery, with electricity at 10 cents/kWh, would cost $5. To go over 300 kms.

Using a Level 2 charger, otherwise known as a destination charger, an EV owner can go about their daily business without ever having to worry about a trip to the gas station or getting home in time before their charge runs out. If they choose, they can always leave home with a 'full tank.'

Level 2, or destination, chargers are found at workplaces, mall parking lots, hotels and motels, car dealerships, Canadian Tire stores, Petro Can stations, and coffee shops etc. (Figure 11).

Figure 12 Level 2Plug Share Network - SW Ontario

Motel owners soon recognized that providing charging stations attracts EV owners wishing to charge their cars overnight. The traveller could then resume their journey in the morning with a fully charged battery. Public Level 2 charging stations are available in most populated areas in Canada (Figure 12)[29]. They are often free to use with the host, such as a hotel, covering the cost of the electricity. They are not as ubiquitous as gas stations, so planning where you stay, and charge is important to the EV driver while almost irrelevant to an ICE vehicle driver.

If the next destination is farther, then the vehicle's range, then a Level 3, or DC fast charging, station is required (Figure 13). Level 3 charger power ratings vary. High output chargers can offer 80% of battery capacity in as little as 15 minutes for cars equipped to accept high rate charging. Otherwise, 30 to 40 minutes is typical.

Level 3 chargers are available in populated areas, along highways and from coast to coast along the Trans Canada Highway. Charging fees vary, but travellers can expect to pay between $10 and $15 for each charge at a Level 3 station.

Figure 13 Level 3 Station

DC fast charging station infrastructure is currently not nearly distributed as widely as gasoline and diesel refuelling infrastructure. Figure 14 shows dc fast-charging station[30] availability in Canada (2020). The rural and northern parts of Canada are not adequately covered while charging infrastructure in southern Canada

[29] Figures 12 was prepared from Plug Share Interactive Map https://www.plugshare.com/

[30] Figures 14 was prepared from Plug Share Interactive Map https://www.plugshare.com/

is adequate. Current infrastructure easily supports cross country trips along major routes. This is true in most advanced economies around the world.

The argument that there are not enough charging stations is quickly becoming moot. Most EVs on the market today have more than adequate range to travel to the next DC fast charging station along cross-country routes in most countries. Public destination chargers are available just about everywhere. An EV owners' daily commute rarely depends on public infrastructure because owners plug their cars in at home. Building on existing, near adequate charging infrastructure is key to enabling EV sales growth.

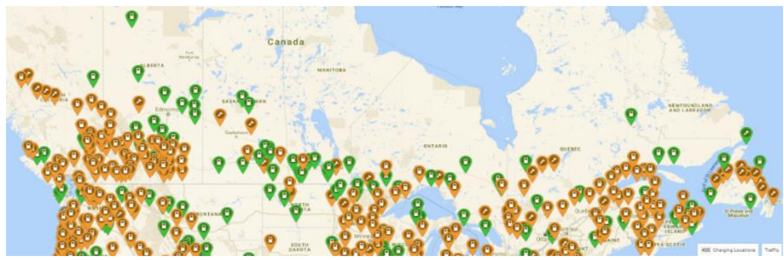

Figure 14 Level 3 Plug Share Network Across Canada (2020)

Government policies, driven by climate change commitments, augmenting private sector investment is leading to rapid growth in charging infrastructure. There are numerous private sector EV charging companies in business today. These companies are growing their station numbers and, in Canada, include EVGo, Plug Share, Charge Hub, Electrify Canada, ChargePoint, Tesla Superchargers.

Like gasoline stations, many DC charging stations offer more than one charging port (Figures 15). According to Business Wire,[31] the charging industry is projected to experience a 33% compounded annual growth rate through to 2023. Wood Makenzie[32] estimates that by the end of this decade, 30 million additional chargers will be installed worldwide.

Figure 15 Tesla Supercharger Station

The currently available and rapidly growing EV charging infrastructure is likely to be capable of supporting the EV growth rates described in this paper. Key to increasing EV market penetration does not seem to be charging options, but the related and less visible topic of battery technology.

g. Battery Technology, Pricing and Performance

Considering all the high-tech features found in most contemporary EVs, rapid advances in battery technology is what is most responsible for enabling the electrification of transport. These advances have made cell phones, handheld power tools, portable computers, and electrified vehicles a reality.

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[31] Business Wire, https://www.businesswire.com/news/home/20191112005454/en/Global-Electric-Vehicle-EV-Charging-Station-Market accessed May 8th, 2020.

[32] https://www.woodmac.com/news/opinion/30-million-ev-chargers-in-the-2020s-grid-edge/ accessed May 19, 2020

Battery development advances involve material science, electrochemistry, manufacturing techniques, economies of scale and likely a suite of other disciplines. These advances are summarized using two performance measures; cost in $/kWh and energy density expressed as kWh/kg. Energy density, kW-hrs/kg, is key to long-range EVs. The higher the energy density, the further an EV can be driven for a given battery mass. Battery energy density at the cell level almost tripled over the past ten years.[33]

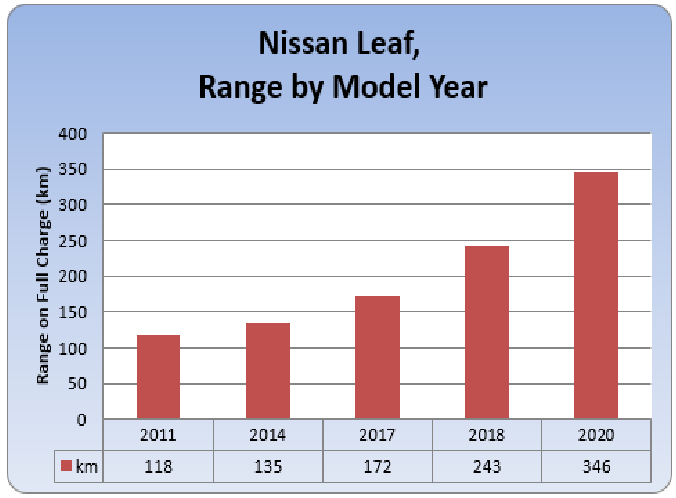

Figure 16 Impact of Battery Energy Density

This means that a 2020 EV can travel considerably farther than a comparable 2010 EV with the battery in both cars weighing the same. Figure 16 shows this performance improvement for the Nissan Leaf. This dramatic increase in energy density coupled with battery cost reductions, is enabling the appearance of heavier vehicles such as pickup trucks, SUVs, commercial vehicles, and buses.

Battery costs reductions have been as disruptive as energy density improvements. EV batteries consist of many cells in a battery pack. Costs for the individual cells, as well as the packs, dropped by over 80% between 2010 and 2019. Figure 17 shows actual (real 2019$) battery pack costs by year over the last decade, along with an estimated cost through to 2030 (US dollars).

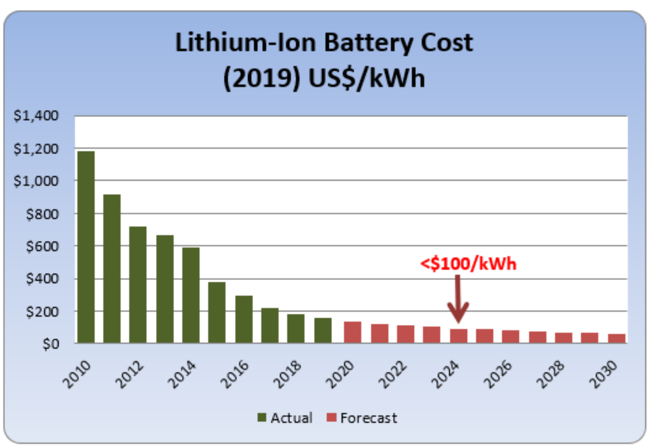

Figure 17 Battery Cost Reduction

This dramatic drop in battery costs leads to vehicle prices approaching price parity across vehicle categories. The price parity challenge for small and low-priced vehicles depends on further battery cost and energy density improvements[34].

The battery price required to facilitate a crossover point between EV upfront cost compared to a similar ICE car is about $100 US/kWh.[35] This is

[33] **Lithium-Ion Battery Cell Densities Have Almost Tripled Since 2010** Colin McKerracher, Head of Advanced Transport at BloombergNEF https://cleantechnica.com/2020/02/19/bloombergnef-lithium-ion-battery-cell-densities-have-almost-tripled-since-2010/ Accessed May 11th, 2020
[34] **Battery pack prices continue plummeting towards price parity with ICE vehicles**, Posted January 27, 2020 by Charged EVs, https://chargedevs.com/newswire/battery-pack-prices-continue-plummeting-towards-price-parity-with-ice-vehicles/ Accessed May 9th 2020
[35] **A Behind the Scenes Take on Lithium-ion Battery Prices**, Logan Goldie-Scot, Bloomberg NEF, March 5, 2019 https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/, Accessed May 9th, 2020

expected to occur before the middle of this decade, as illustrated in Figure 17. When battery prices drop to that level, it will cost more to buy an ICE vehicle than a comparable EV: a tipping point.

The middle of this decade is likely to be when that tipping point occurs. This coincides with our estimate of when there would be enough EVs in global service to disrupt crude oil demand significantly. This is coincidental because the factors considered in this section involve battery and EV price/cost fundamentals, not sales projections.

Factors discussed earlier use actual EV sales and policy influence to estimate when global EV stocks will exceed 40 million EVs. A global fleet of 40 million EVs will inevitably lead to less gasoline and diesel fuel consumption and in no way resembles a complete transition to electrification of transport.

There does not need to be a complete transition to electric vehicles to cause a permanent disruption in oil industry economics. And basic economics suggest high-cost producers will be impacted first.

5. Can this Happen Within a Decade?

Have you tried to buy a film camera[36] lately? Or a CRT (not flat screen) TV? How about NiMH batteries? A videocassette recorder or VCR tapes? Without mentioning social media or smartphones, the list of disrupted technologies and services over the past decade or so is extensive.

Figure 18 Kodak 35mm Camera

Note, you can still buy film cameras (Figure 18), use a landline rather than a cell phone, or send documents by surface mail. These 20th-century technologies still exist, but the scale is trivial compared to what they were only a few years ago. By mid-decade, EVs may not completely displace ICE vehicles, but enough of them could be in service to disrupt the crude oil supply/demand balance permanently.

We have seen this before.

[36] Kodak camera image https://unsplash.com/photos/yXwdLSYSaFc accessed July 20, 2020

Easter Sunday Parades on 5th Avenue – New York City

1900 – One Automobile **1913 – One Horse Drawn Buggy**

Figure 19 Rapid Technology Driven Change

At the turn of the last century, the primary motive power for transportation was the horse. A mere thirteen years later, that changed to motor vehicles. As is pointedly shown in Figure 19, the transition from horses to cars only took 13 years. Note that horses did not disappear from the transportation scene by 1913, but a disruptive and irreversible change happened; within 13 years. One technology replaced another because it was better.

From a historical perspective, we have seen significant disruptions in technology happen astonishingly fast across industry sectors, including transportation. We should not rule out the possibility of history repeating itself.

A wide assortment of affordable, fully electric cars is now available that can travel in the range of 300 to 500 km or more on a single charge. Short and medium-range electrified buses and commercial trucks are currently in service, with several vendors planning to market long-range trucks before the end of this decade[37]. Short to medium range electric aircraft are in development by world-class aircraft manufacturers[38]. Deployment of commercial medium-range, all-electric passenger aircraft is planned for this decade, in less than ten years.

This transition to electrified transportation is underway. This leads to the question, is the electricity supply infrastructure to support this pace of change in place now, or can it grow at a pace fast enough to sustain these growth rates?

[37] https://www.greencarreports.com/news/1129021_tesla-and-nikola-electric-semis-will-arrive-to-rivals-from-traditional-truck-makers

[38] **Boeing completes test flight of autonomous electric passenger aircraft**. Austin, R. (2019, February 12). *Charged Electric Vehicle Magazine.* https://chargedevs.com/newswire/boeing-completes-test-flight-of-autonomous-electric-passenger-aircraft/

6. Electrification of Transportation and Electricity Supply

Before the COVID-19 pandemic, the world used almost 100 million barrels of oil per day, a massive amount of energy, much of which was consumed by transportation[39]. Do we have the capacity to start transitioning this load away from oil to our electrical systems? ICE vehicles powered by either gasoline or diesel have different energy requirements than for cars powered by electricity. Electric motors are 90+% efficient at turning electrical energy into mechanical energy to move the vehicle. However, a typical ICE vehicle is under 30% efficient at converting the energy in its fuel to move the vehicle[40]. Also, electric drives incorporate efficiency systems such as zero idle and regenerative braking.

Assuming about 70 litres of gasoline can be produced from each barrel of oil, then one barrel of oil can be replaced by 177 kWh of electricity. If enough ICE vehicles are displaced by EVs to reduce global oil consumption by two million barrels a day, about 2% of global demand, then we would need to generate an additional 128 TWh of electricity to power those vehicles.

According to the BP Statistical Review of World Energy 2019, in 2018 the world generated over 26,000 TWh of electricity. The additional 128 TWh required to power EVs and reduce oil consumption by two million barrels a day, would then require an increase of about 0.5% in generation. However, growth in global electricity generation averaged 2.5% annually over the last ten years. It would only require a modest increase in generation growth to accommodate a partial shift from ICE vehicles, the equivalent of 2 million barrels of oil per day. So, what are the factors influencing incremental supplies of electricity to service this new and growing load on the system?

a. Factors Affecting Incremental Electricity Supply

For well-established electricity jurisdictions such as those in North America, the transition to EVs presents mainly opportunities and only a few problems.

Electricity demand follows daily, weekly, and seasonal patterns, with average demand being less than 75% of peak demand and nighttime troughs sometimes below 50% of peak demand. This means a lot of generation is idle during these low demand periods, mainly at night. So additional load to recharge EVs at night is beneficial in that it helps better use baseload and intermittent generation, helping to reduce average electricity costs.

However, the distribution system in some residential areas needs upgrading to satisfy the increased loads. But even here, the more progressive local distribution companies (LDC's) are finding benefits. Integrating Wi-Fi enabled individual vehicle chargers with LDCs lets them utilize the energy stored in the vehicles (Vehicle to Grid, or V2G) to reduce peak consumption costs while still ensuring fully charged cars are available when required.

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[39] For a discussion on energy in different forms applied to transportation see Canada: Making the Case for Nation Building Projects, Chapter 5 Joules in a Decarbonized Economy.

[40] 2020 Volkswagen e-Golf rated at 2.1L/100km, ICE Golf 7.4L/100km. Chevy Bolt rated at 2.0L/100 km, Chevy Cruz (approx. equivalent) rated at 7.4L/100 km.

Annual average electricity generation growth rates of the rapidly developing countries in Asia-Pacific are growing at 5%, with India at 6% and China at 7%. Provided economic growth continues post COVID-19 these are the areas forecasting the greatest increase in new vehicle sales, and it appears, they can meet any increased demand from EVs.

To developing countries, the transition to EVs presents a huge opportunity. Typically, developing countries have one thing in abundance, sunshine. With the declining cost of solar generation and the ability to scale up solar arrays to meet growth, without the need for costly transmission infrastructure, developing nations can meet their own energy needs. Rather than send billions of dollars out of their countries each year to pay for oil imports for transportation and coal for electricity, they are motivated to generate low-cost renewable electricity. Doing so will keep their money at home to be used to improve living standards. We can expect to see developing nations continue to encourage the transition to EVs and to solar generation.

7. What Can Oil Sands Proponents Do?

John F Kennedy famously said, "*Change is the law of life. Those who look only to the past or present are certain to miss the future*". In the context of change, consider the words Wayne Gretzky reportedly said*, "move to where the puck will be, not where it is now."*

a. Innovation and Innovators Dilemma

In his 1997 book *The Innovator's Dilemma* Harvard professor Clayton Christensen describes a situation where business leaders need to decide to stay with proven business practice or imagine new approaches to their business. This leads to a dilemma, continue with the old and risk stagnation or risk innovation but with potentially high rewards.

Businesses that listen too closely to customer feedback can easily fall into the trap of stagnation, even though they reacted directly to what their consumers wanted – or at least what consumers thought they wanted.

Market research only tells innovators so much. Consumers are not necessarily the best judges of what they want (Figure 20).[41]

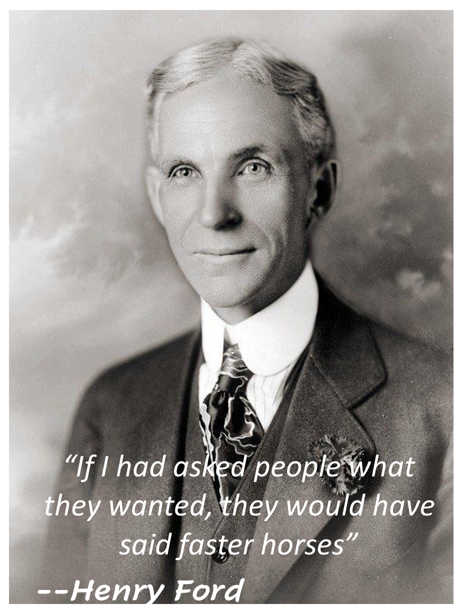


Figure 20 Innovators Dilemma

One example of a company that fell afoul of the Innovator's Dilemma is Blockbuster. The video rental giant dominated its sector in 2000 and bankrupt by 2010. Blockbuster failed because it chose to stick with its rental model rather than seize opportunities offered by on-demand streaming technology. Another example comes from the photo industry.

[41] Innovators Dilemma image from https://pixabay.com/photos/henry-ford-portrait-man-suit-tie-63113/

Electric Vehicle Impact on the Oil Sands

Kodak did not fail because it missed the digital age. It invented the first digital camera in 1975. Instead of marketing the new technology, the company held back for fear of hurting its lucrative film business, only to see film sales slump as better technology replaced film.

Businesses can continue doing what they think is working well or pay attention to market signals and adopt disruptive advancements to stay relevant. All companies face that predicament. And it applies to the Oil Sands.

b. Specific Actions

As of March 2020, the Energy Sector of the Canadian Economy represented 7% of GDP, and almost 300,000 high paying jobs.[42] This is too important to the Canadian economy for policymakers to ignore. Therefore, a rational transition plan needs development and implementation due to supply issues outside Canadian control, and the structural demand changes happening around the world.

i. Bitumen Beyond Combustion[43]

Bitumen represented a valuable resource for use as fuels in the 20th century and the beginning of this century. As the world weans itself from hydrocarbon fuels, this resource offers opportunities unique in the spectrum of crude oils.

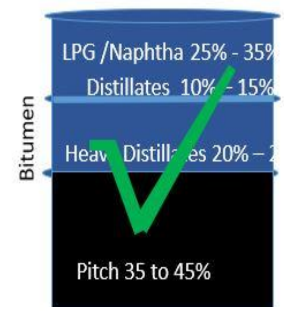
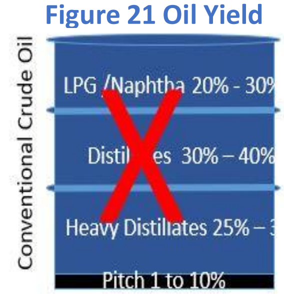


Figure 21 Oil Yield



High carbon content materials such as carbon fibre, graphene, including conventional products such as coatings, asphalt, and sealants, can be produced from the ‘bottom of the barrel’ of crude oil. Historically, the bottom of the barrel has been assigned an extremely low value because of the cost and complexity of turning it into fuels

Repurposing bitumen ***FROM*** a fuel ***TO*** a materials resource could transform bitumen into a crude oil of choice, turning price discounts into premiums.

WHY?

Bitumen’s unique properties and chemical makeup make it a valuable resource as it contains a rich supply of building blocks for a wide array of value-added high carbon content materials. Bitumen contains about 40% high carbon content molecules, much higher than conventional crude oils, which range from 1 to 10% (Figure 21). Typically, less than 5%. This means conventional crude oils are the wrong feedstock for manufacturing advanced high carbon content materials and chemicals. Bitumen can be processed into market-ready materials such as premium asphalt or near market-ready technologies to produce carbon fibre to emerging products such as graphene and others.

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[42] Statistics Canada. Table 36-10-0103-01 Gross domestic product, income-based, quarterly (x 1,000,000)

[43] Term coined by Alberta Innovates, https://albertainnovates.ca/focus-areas/clean-resources/bitumen-beyond-combustion-bbc/

Electric Vehicle Impact on the Oil Sands

In a world of surplus fuel, refiners using crude oil for manufacturing durable products will need to find outlets for the fuel portion of their product slate. Like sulphur and coke today, the less fuel you need to get rid of, the more profit to be made on the materials component of the business. Because bitumen contains more pitch than most crude oil, when using it to produce high-value durable products, bitumen processors will have less low valued fuels to sell to oversupplied customers.

In parallel with re-imagining bitumen, detailed transition plans need to be developed for negatively impacted people. The impacts are already being felt. The time for **talk** about transition plans is over. The plans are required now, and plan execution needs to be underway. There is no downside. If we are wrong, then we will have created valuable jobs in addition to those that might be restored in the unlikely event oil markets return to conditions not seen for years.

ii. Transition Plan

Whether or not political leaders, labour leaders, and workers are ready, a transition is going to occur, and likely within the next few years. The timing for this transition coincides almost perfectly with another significant job initiative. But that initiative needs to be taken seriously as it could offset the likely impact on the Oil Sands sector.

Western provinces have committed to decommissioning their coal-fired power stations by the end of this decade. Other jurisdictions are doing this, including the UK, Australia, Ontario, and others. These jurisdictions did some things well during these transitions, as well as made mistakes. Their experiences are well documented and should be examined for their applicability to ensure a successful transition.

The Government of Canada and the World Bank have well-developed plans and mechanisms designed to aid this transition[44] [45]. Recognizing that even a limited penetration of electrified vehicles could seriously jeopardize the Oil Sands sector suggests the development and implementation of a transition plan must be a top priority for affected provinces and the Federal Government.

Alongside the transition from coal for thermal electricity generation, targeted training with links to new energy skills is essential to creating jobs for newly trained people. In addition to displacing fossil energy for renewable energy, its time to recognize that 'if you can't beat them, join them.'

Provinces and the Federal Government should invest in electrification of transport, not only for environmental reasons but in the interest of jobs. By adding charging infrastructure, promoting Canadian lithium resources, and enticing battery and vehicle manufacturers to Canada will help mitigate threats to jobs not only in the Oil Sands sector but also in vehicle parts and assembly plants. Alberta has significant lithium resources. At least one Alberta company[46] is on track to commercialization. Leading to the question, could Alberta entice a battery manufacturing facility to locate near the resource?

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[44] **Task Force: Just Transition for Canadian Coal Power Workers and Communities**, https://www.canada.ca/en/environment-climate-change/services/climate-change/task-force-just-transition.html

[45] **Managing Coal Mine Closure: Achieving a Just Transition for All** http://documents.worldbank.org/curated/en/484541544643269894/Managing-Coal-Mine-Closure-Achieving-a-Just-Transition-for-All Accessed June 10, 2020.

[46] E3 Metals Corp. https://www.e3metalscorp.com/

Electric Vehicle Impact on the Oil Sands

As part of the transition plan, the provinces and the Federal Government need to be aggressively recruiting battery manufacturers to locate in Alberta and other provinces containing battery material resources (carbon, lithium, nickel, cobalt). Vehicle manufacturers are spending hundreds of billions of dollars to develop electric and autonomous vehicles. The transition plan needs to attract some of that investment to Canadian jurisdictions, and now.

There is controversy surrounding battery material extraction, especially cobalt. Canada would fare well in a Life Cycle Assessment (LCA) around battery production in this country due to our well-developed environmental assessment and performance capabilities. We would kick ass!

While this is happening, the transition plan should include steps to help improve the short-term economics of bitumen production to buy a few years' grace to implement the transition plan fully.

iii. Resource High Grading

In the immediate term, there may be a way to improve bitumen extraction economics while significantly reducing GHG emission intensity and other environmental impacts from bitumen extraction.

Bitumen is extracted from ores containing between 8-14% oil. Operators are required to produce oil from the resource even if it is lean in oil. By allowing producers to select oil-rich ore - high-grading - costs, and environmental impact intensity would drop, leading to a short-term profitability increase.

Given the glut of oil on the market today, coupled with global decarbonization, it is unlikely the bitumen resource will be exhausted. Government policy and mine plans should be designed with that in mind.

Success would take the form of the Alberta government actively encouraging operators to high grade. Executing a high grading philosophy would reduce emission intensity, water use, tailing pond size, improve profitability, secure jobs, and add wealth for as long as the Oil Sands remain viable.

8. Conclusion

Do not expect the transition to electric vehicles to be slow. The transition from horse-drawn carriages to cars only took 13 years and was unexpected and disruptive. Compelling signals suggest we may see history repeat itself. A partial transition could impact the oil sands by the middle of this decade.

This paper provided a status on the electrification of transport and its implications on the Oil Sands in the context of fossil fuels. This information drives us to identify and evaluate options to enable producing provinces and Canada to move forward. Not only to participate in what appears to be a transportation technology disruption but to lead and profit from the changes already underway.

We must not allow the innovator's dilemma or fear of loss in economic activity coupled with our natural resistance to change to delay us. Change is happening and happening fast. A shift in mindset is required.

Electrification of transport is often presented as a problem; we ignore it at our peril. Rather than succumb to the innovator's dilemma and shy away from change, we must embrace it, find the opportunities, and pursue them.

The opportunities are abundant. We need to seize the moment and grasp the opportunities. These opportunities include, but are not limited to;

- Develop and commercialize the physical and chemical properties unique to bitumen to produce materials for durable goods (BBC). Examples include premium asphalt, carbon fibre, graphene, pure carbon, and 21st century materials not developed yet.
- Define Canadian roles in the expanding EV sector, ranging from raw material extraction (Li, Ni, Co, C, etc.) manufacturing batteries, vehicle components and vehicle assembly.
- Build on existing Canadian EV charging infrastructure to encourage electrified transportation investors.
- Turn the transition from fossil fuels to other energy sources into a job producing bonanza
- Supply low carbon electricity for this new and rapidly expanding sector as part of an integrated national high-voltage grid system with access to the US power market.

Canada has the prerequisites to lead and prosper as these 21st century transitions unfold. And the evidence is clear; significant changes are underway. But there is a risk that we will revert to the tried and true that worked in the last century. So, we need a transition plan that recognizes the signals and defines a path forward, then implement the plan within the mandate of current provincial and Canadian governments.

Electric Vehicle Impact on the Oil Sands

We have an opportunity to create thousands of new jobs, advance Canadian technology, sustainably develop Canada's abundant human and natural resources and provide wealth and prosperity to all regions of our nation.

As discussed earlier, this transition is global in scale, disruptive in nature, and is already well underway. It is unstoppable. Continued progress in Canada requires decisive, visionary, and courageous leadership. Leaders who acknowledge the technological and market realities, seize the opportunities, and implement a nation-building plan to transition towards the new reality.

In addition to leadership, we will need an informed public; plus, corporate, political, and Indigenous people's involvement. Such a national scale engagement will transform this threat into a nation-building opportunity.

Appendix 1 Calculation Method How Many EV's to Cause a Supply – Demand Imbalance

1 barrel = 42 US gallons = 159 litres. According to the US EIA, a typical refinery produces about 19 US gallons of gasoline and about 11 US gallons of diesel fuel per barrel of oil, or, each barrel of oil will produce about 30 (111 Litres) US gallons of fuel/barrel. Divided by 42 US gallons/barrel = ~70%.

We assumed the average ICE vehicle across all services, including personal, light-duty commercial, delivery vans and trucks and intra-city buses, use 10 litres of fuel per 100 km.

We assumed the average ICE vehicle in personal, light-duty commercial, delivery vans and trucks, and intra-city buses travel 20,000 km/hear.

Based on these assumptions, ICE vehicles in all services around the world consume:

20,000 km/year x 10 Litres/100 km = 2,000 litres of gasoline and diesel (plus lubricants) per year

2,000Litres/yr. divided by 159 Litres/barrel = 12.6 barrels of fuel/year for each ICE vehicle in all services.

To manufacture that amount of fuel from crude oil requires 12.6 barrels of fuel/year divided by 70% = 18 barrels/yr of crude oil, on average.

To lead to a supply-demand imbalance of 2 million barrels per day would require 365d/yr. x 2,000,000 barrels(/d) divided by 18 (barrels/per EV per yr.) = 40.6 million ICE vehicles to be displaced by EVs.

Smell Test Method
Notional Global Oil Demand is 100,000,000 barrels/day (2019)

In 2014 oil price dropped from ~100 to ~US 40$/barrel due to a 2,000 barrel/day production surplus over demand, about 2%. Assume that 2% of the world's ICE vehicles burn that amount of fuel.

In 2019 there were about 1.3 billion [47] ICE vehicles in service on the world's roads. Multiplying 1.3 billion vehicles by 2% results in almost 30 million EVs. This suggests average fuel consumption and km driven per year used in the method above might be low. Taxis, intra-city delivery trucks, city buses, fleet vehicles are more fuel-intensive and driven further than the average light-duty vehicle used for personal transportation. Vehicles in these fuel-intensive services are being electrified.

In conclusion, somewhere between 30 and 40 million EVs will lead to a supply-demand imbalance of 2,000,000 barrels/day of oil. Experience from 2014 and pre-COVID-19 (December 2019) revealed that an imbalance of that magnitude would cause rationalization in the crude oil production sector and long-term prices in the range of US 40$/barrel.

This suggests a small transition to electric vehicles will lead to a long-term oil price issue.

[47] Cars Worldwide, https://www.live-counter.com/number-of-cars/

Appendix 2 Countries planning to Ban Sale of New Fossil Fueled Cars[48]

Rank	Country	Ban Start Date
1	China	2040
2	Costa Rica	2021
3	Denmark	2030
4	France	2040
5	Germany	2050
6	India	2030
7	Ireland	2030
8	Israel	2030
9	Japan	Ongoing
10	Netherlands	2030
11	Norway	2025
12	Portugal	Ongoing
13	South Korea	2020
14	Spain	2040
15	Taiwan	2040
16	UK (Except for Scotland)	2040
17	UK (Scotland)	2032

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By Sophy Owuor

48 https://www.worldatlas.com/articles/countries-that-will-ban-gasoline-cars.html, accessed May 1st, 2020

Appendix 3 Sub-National Jurisdictions Planning to Ban Sale of New Fossil Fueled Cars[49]

Cities and territories [edit]

Some cities listed have signed the Fossil Fuel Free Streets Declaration, committing to ban emitting vehicles by 2030,[22] but this does not necessarily have force of law in those

City or Territory	Country	Ban announced	Ban commences	Scope	Selectivity
Amsterdam	Netherlands	2019	2030[23]	Gasoline or Diesel	All vehicles
Athens	Greece	2016	2025[24]	Diesel	All vehicles
Auckland	New Zealand	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
Balearic Islands	Spain	2018	2025–35[25]	Gasoline or Diesel	All vehicles
Barcelona	Spain	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
Bristol	United Kingdom	2019	2021[26]	Diesel	All private vehicles (city center from 7 am to 3 pm)
British Columbia	Canada	2018	2025[27]	Gasoline or Diesel	All vehicles by 2040, 10% ZEVs by 2025
Brussels	Belgium	2018	2030[28]	Diesel	All vehicles
Cape Town	South Africa	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
Copenhagen	Denmark	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
Hainan	China	2018	2030[29]	Gasoline or Diesel	All vehicles
Heidelberg	Germany	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
London	United Kingdom	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
Los Angeles	United States	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
Madrid	Spain	2016	2025[24]	Diesel	All vehicles
Mexico City	Mexico	2016	2025[24]	Diesel	All vehicles
Milan	Italy	2017	2030[4]	Diesel	All diesel vehicles, electric buses by 2025
Oxford	United Kingdom	2017	2020–35[4]	Gasoline or Diesel	All vehicles (initially during daytime hours on six streets)[30][31]
Paris	France	2016	2025[24]	Diesel	All vehicles
Quito	Ecuador	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
Rome	Italy	2018	2024[32]	Diesel	All vehicles
Seattle	United States	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025
Vancouver	Canada	2017	2030[4]	Gasoline or Diesel	All vehicles, electric buses by 2025

[49] https://en.wikipedia.org/wiki/Phase-out_of_fossil_fuel_vehicles Accessed May 1st 2020