Alternative Fuels Comparison

Advantages of LNG vs. Other Low Carbon Fuels to Displace Diesel in Class 8 Long-Haul Trucking

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Acronyms Included in this Document

- BEV – Battery Electric Vehicle
- CNG – Compressed Natural Gas
- CI – Carbon Intensity
- CO_2eq/MJ – Carbon Dioxide Equivalent per Megajoule
- CVI – Cool Ventures Inc. (“Cool”)
- DCFC – Direct Current Fast Charger
- EIA – U.S. Energy Information Administration
- FCEV – Hydrogen Fuel Cell Electric Vehicle
- GGE – Gallon Gasoline Equivalent
- GHG – Green House Gas
- GVWR – Gross Vehicle Weight Rating
- ICCT – International Council on Clean Transport
- Mt – Metric Tonnes
- LCNG – Liquefied Compressed Natural Gas
- LNG – Liquefied Natural Gas
- MSRP – Manufacturers Suggested Retail Price
- NGVA – Natural & Bio Gas Vehicle Association
- NOx – Nitrogen Oxides (Nitric Oxide and Nitrogen Dioxide)
- NREL – National Renewable Energy Laboratory
- RNG – Renewable Natural Gas
- SMR – Steam-Methane Reforming
- TCO – Total Cost of Ownership
- Wh/L – Watt-hours per Litre (Energy Density of Battery)
- ZEV – Zero Emissions Vehicle

Preface

Basis for this Alternative Fuels Comparison

In September 2021, the U.S. National Renewable Energy Laboratory ("NREL") published a report titled "Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks" (the "NREL Report").

The NREL Report focused on providing a first-of-its-kind, rigorous, techno-economic analysis of emerging, alternative fuel powertrain technologies for use in the medium- and heavy-duty transportation sector. Specifically, the NREL report evaluated Total Cost of Ownership ("TCO") for:

- Six different powertrain technologies (Diesel, Diesel Hybrid Electric, Plug-in Hybrid Electric, Compressed Natural Gas ("CNG") Battery Electric and Hydrogen Fuel Cell Electric);
- Three different truck vocations (Class 8 Long-Haul, Class 8 Short-Haul, and Class 4 Parcel Delivery); and
- Three different time frames (2018, 2025, and Ultimate (2050)).

The NREL Report concluded that "medium- and heavy-duty trucks with battery and fuel cell electric powertrains could be economically competitive with diesel powertrains under several operation scenarios as early as 2025 for shorter-range applications (<500-mile Class 8 tractors, 120-mile Class 4 delivery) if high diesel prices and low hydrogen/electricity prices are realized." The NREL report also found that in the Class 8 Long-Haul vocation, Battery Electric and Hydrogen Fuel Cell vehicles are very competitive with diesel if Ultimate scenario assumptions are met.

The short coming of the NREL report however, is that the TCO modeling framework the NREL used did not account for many real-world considerations important to alternative fuel powertrain adoption such as:

- Availability of infrastructure (ex. placement, sizing, rollout strategy, cost, grid integration, investment and operations);
- Feasibility of overcoming existing technological barriers to adoption (ex. improving battery energy density); and
- Necessity for a near-term (>5 years) alternative fuel solution to effectively reduce Class 8 Long Haul emissions.

This Alternative Fuels Comparison focuses on the data and assumptions from the NREL report in respect to Diesel, CNG, Battery Electric and Hydrogen Fuel Cell Electric for the Class 8 Long-Haul vocation. It recognizes Liquefied Natural Gas ("LNG") as an emerging, alterative powertrain technology, and has supplemented the data from the NREL report with other sources to provide a brief but practical alternative fuels comparison that encompasses real-world considerations and the availability of present-day technology to determine the best market-ready fuel alternative to diesel.

This Alternative Fuels Comparison examines the material through a Canadian context. All amounts are expressed in Canadian dollars (C$) unless otherwise noted.

Overview

Introduction

The adoption of low carbon intensity fuels is critical to reducing emissions in hard to abate industries such as Class 8 Long-Haul trucking (>1200km range, 80,000lbs gross vehicle weight rating ("GVWR")).

Government policies have been created and are becoming more stringent to provide incentives to invest in the development and adoption of low carbon fuels. Trucking fleets are facing pressure to transition in the near-term from conventional fuels like diesel, or face increasing financial penalties through carbon taxes and other escalating prices on pollution.

Class 8 Trucking Fuels Evaluated

Diesel	Battery Electric ("BEV")	Hydrogen ("FCEV")	CNG	LNG

The Need For Alternative Fuels

Canada's transportation sector is the second-largest contributor to overall GHG emissions, and since 2005, emissions from the transportation sector have increased by 16%. According to data from the most recent National Inventory Report (2021), emissions from transportation were 186Mt in 2019, accounting for 25% of total emissions in Canada(1).

To achieve its climate targets, Canada's largest sectoral emissions sources must significantly reduce the carbon intensity of their operations and to ensure this, the Federal Government has established an escalating carbon tax:

- The carbon tax started at $20 per tonne of emissions in 2019 and has been rising at a rate of $10 per year to now reach $50 per tonne in 2022. In April 2023, the price will start rising by $15 per year until it reaches $170 per tonne in 2030.

Recognizing the essential role of cleaner fuels to achieving emission reductions, Canada has also published Clean Fuel Regulations, coming into effect July 2023, which will require liquid fossil fuel (gasoline and diesel) suppliers to reduce the carbon intensity of the fuels they produce and import for use in Canada over time. The Government expects that the Clean Fuel Regulations will result in decreasing the carbon intensity of liquid fossil fuels by approximately 15% below 2016 levels by 2030(1).

Together, these policies create cost pressure for Class 8 Long-Haul trucking fleets to switch from Diesel to lower carbon intensity fuels. This document will examine the viability of powertrains using Battery Electric, Hydrogen, Compressed Natural Gas ("CNG"), and Liquified Natural Gas ("LNG") to displace Diesel as a fuel for Class 8 Long-Haul trucking, and why LNG is the best alternative fuel.

Criteria For Assessing Fuel Viability

1. Purchase Price of Powertrain
2. Fuel Cost
3. Driving Range
4. Operating and Maintenance Cost
5. Time to Refuel
6. Payload Capacity
7. Carbon Intensity of Fuel
8. Barriers to Adoption
9. Availability

Overview - A Transition Away From Diesel

Diesel powertrains afford features including high power density, energy-efficiency, high-uptime, reliability, durability, driving range, payload carrying capacity, and extensive servicing and fueling networks.

- In addition to offering a comprehensive suite of features, the cost of owning and operating trucks with diesel powertrains has been economical thanks to diesel prices, which have historically been cost competitive with gasoline, and the high efficiency of diesel powertrains.

These factors are paramount to trucking business operations, whose profit margins are slim and center around shipping velocity - the more freight you can deliver per unit of time while keeping your costs down, the more profit.

The problem that Class 8 trucks with diesel powertrains face is that the total cost of ownership is increasing rapidly due to rising fuel costs associated with climate policies and commodity supply constraints, the effects of which are being felt already.

Trucking fleets need an alternative fuel powertrain with features that will allow the truck to complete the same routes and ranges as a diesel powertrain, an economic total cost of ownership, and a carbon intensity that will comply with environmental legislation.

Renewable Diesel & Biodiesel Lack Sufficient Feedstock Supply

Renewable diesel is made from extracting oil from plants including canola, palms, peanuts, soybeans and sunflower seeds. It can also be produced from waste oils, including used cooking oils, and blending with conventional diesel could lower the carbon intensity of the fuel by as much as 50%.(2)

- In the U.S., a leader in Renewable Diesel production, there is not enough feedstock to make renewable diesel commercially viable. According to the International Council on Clean Transportation (the “ICCT”), the U.S. currently has about 800 million gallons of renewable diesel production capacity per year, with new projects planned to increase total capacity to 5 billion gallons per year by 2024. These potential facilities at full capacity would create 17 million metric tonnes of additional demand for waste oils and fats. (2)
  - ✓ In 2020, diesel consumption by the U.S. transportation sector was about 44.61 billion gallons, as per the EIA.
- While predicted increases in U.S. domestic soy oil production could support up to 300 million additional gallons of production and increased utilization of waste oils another 150 million gallons, beyond this, increasing production would mean dramatic, unforeseen expansion of domestic soy and canola acreage, dramatic increases in canola or palm oil imports, or massive displacement of feedstock from other uses (or a combination of the three). (2)
- The ICCT expects that some projects will be delayed, cancelled, or run far below nameplate capacity, as excessive growth in biomass-based diesel production could cause market distortions leading to massive price increases and escalate CO_2 emissions from land use change. (2)

Purchase Price (MSRP)(3)

$208,000

Fuel Cost(4)

$5.8/GGE

Driving Range(5)

2000km+

Operating & Maintenance Cost(3)

$0.09-$0.15/km

Time to Refuel(3)

5-10 min

Payload Capacity(3)

>50,000lbs

Carbon Intensity(6)

96gCO_2eq/MJ

For citations, please refer to “Sources” on page 13.

Battery Electric

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Price & Range Hinder Battery Electric Adoption[1]

Referred to as "zero-emissions-vehicles" ("ZEVs"), Battery Electric powertrains and the electrification of the Class 8 long-haul transportation sector will require significant innovation before widespread adoption can occur:

- The volume available to install an electric battery onboard a class 8 truck has a feasible range of 0.3 – 5.0m^3. An 800km range battery electric powertrain with a fuel economy of 24km/GGE requires a 1,120-kWh battery, and at an energy density of 530 Wh/L the battery size is 2.1m^3. For longer range requirements, the size of the battery may exceed available onboard volume unless technology improves the battery energy density to offset the increase in energy requirement.
  - ✓ With current battery energy density, battery electric powertrains weigh approximately 7,000 pounds more than diesel powertrains with a comparable energy capacity.
  - ✓ As the required range for a trip increases, factors such as refueling time, availability of charging infrastructure, lost payload capacity due to battery weight, and electricity price become more costly.
- Electricity prices for heavy-duty trucks are highly uncertain, given the local rate structure and high-power requirements that may be needed for direct current fast chargers ("DCFCs") or extreme fast chargers. Current DCFC rates for light-duty vehicles (up to 150 kW) across the United States average higher than $12.8/GGE.
  - ✓ Electricity price is very important to the total cost of ownership of the battery electric powertrain, and today's prices observed for public DCFC's would not be economically attractive and significantly increase total cost of ownership.
- Current DCFC prices may be based on low utilization and limited economies of scale, but the high-power requirements needed to charge batteries of the size that would be required for Class 8 Trucks may result in higher demand charges (e.g. a 2-MWh battery charging in 1 hour requires 2-MW charging).

Infrastructure Considerations [1]

As the battery electric trucking industry is in its infancy, the current refueling/recharging infrastructure is insufficient to support widespread vehicle adoption by fleets. Clearly, without sufficient refueling and/or recharging, fleets would not be able to operate.

- Detailed infrastructure analysis around the placement, sizing, rollout strategy, cost, and renewable energy and grid integration optimization of widespread charging has not been considered when determining the feasibility of battery electric powertrains.

According to the NREL, battery electric powertrains may be suitable for lower-density goods transport with lower total weight, or for applications with shorter range requirements.

- Improvements in technology that allow for strong cost reductions in electricity price, battery cost, dwell time, and payload costs are needed before battery electric powertrains are remotely cost competitive for Class 8 long-haul trucking.

Purchase Price (MSRP) [1]

$ 1,030,000

Fuel Cost [1]

>$12.8/GGE

Driving Range[1]

800km

Operating & Maintenance Cost[1]

$0.08-$0.11/km

Time to Refuel[1]

30-60 min

Payload Capacity[1]

~35,000lbs

Carbon Intensity[2]

48gCO_2eq/MJ

Hydrogen Fuel Cell Electric

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Status of Hydrogen Technology Unsuitable for Adoption

Like battery electric powertrains, hydrogen fuel cell electric powertrains will require significant innovation before widespread adoption can occur:

- As per the NREL, hydrogen powertrains require technological breakthroughs that will allow fueling from cost-effective liquid hydrogen tankers or on-site generation of hydrogen. With current technology hydrogen prices from gaseous tube trailers are too high. Storage of hydrogen as a liquid would require cooling the hydrogen to minus 252.8°C, and as of April 2022 gaseous hydrogen prices averaged $21.30/GGE, based on limited available data.[1][2]

The majority of hydrogen currently produced in North America is made by steam-methane reforming ("SMR"), a process in which high-temperature steam is used to produce hydrogen from methane contained in sources such as natural gas. There is serious interest in producing hydrogen at scale through electrolysis from renewable energy sources such as wind, hydro and solar.

- Hydrogen use in transportation is assumed to be in proton exchange membrane fuel cells, in which hydrogen is used to create electricity and water. Therefore, there are no direct greenhouse gas emissions associated with the use of hydrogen in fuel cell technology, although there are emissions associated with hydrogen fuel production:
  - ✓ The Canadian average carbon intensity for hydrogen from SMR with liquid truck delivery is 114gCO_2eq/MJ. The Canadian average carbon intensity for hydrogen produced from electrolysis with liquid truck delivery is 75gCO_2eq/MJ, although it could be as low as 34gCO_2eq/MJ when produced in provinces with hydropower like B.C.[3]
  - ✓ As diesel has a carbon intensity of 96gCO_2eq/MJ, hydrogen fuel displacing diesel must be produced through electrolysis or other renewable methods in order to reduce the carbon intensity of transportation and comply with regulations.

Infrastructure Considerations

The hydrogen trucking industry is in its embryonic stages, and the current refueling infrastructure is insufficient to support widespread vehicle adoption by fleets. In addition to refueling infrastructure, capacity for production of low carbon hydrogen from renewable methods such as electrolysis must be built to scale as well.

According to the NREL, strong improvements in fuel cost, operating and maintenance cost, and hydrogen storage cost are required before fuel cell powered trucks can achieve a total cost of ownership competitive with Class 8 long-haul diesel powertrains.[3]

- The NREL suggests that hydrogen fuel cell electric vehicles could be suitable for long range applications, citing a Driving Range of 1450km, although the U.S. Hydrogen and Fuel Cell Technologies Office states that it is still working to develop onboard automotive hydrogen storage systems that allow for a driving range of more than 300mi (~480km) while meeting cost, safety and performance requirements.[4]

Purchase Price (MSRP)[1]

$487,000

Fuel Cost[2]

$21.30/GGE

Driving Range[4]

480km

Operating & Maintenance Cost[1]

$0.12-$0.28/km

Time to Refuel[1]

10 min

Payload Capacity[1]

~50,000lbs

Carbon Intensity[3]

75CO_2eq/MJ

Natural Gas

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The Role of Natural Gas in Decarbonizing the Transportation Sector

"To avoid the atmospheric carbon dioxide "overshoot" featured in recent IPCC reports and other analyses there is an urgent need to quickly and drastically reduce greenhouse gas emissions. The world pins its hopes on new technological breakthroughs, but some of those breakthroughs may be decades away. In the context of limited world financial resources, the need for fast, gigaton-scale greenhouse gas emission reductions logically points to finding near-term, low-cost emissions reductions opportunities. Prudent use of natural gas may provide some of those opportunities. The perfect is often the enemy of the good. Let us not let our hopes and efforts for a perfect future deter us from doing good immediately. " [1]

- Natural gas, as the cleanest fossil fuel, both in terms of conventional pollutants such as sulfur dioxide, particulate matter, and mercury, as well as greenhouse gas emissions per unit of energy produced, is a logical starting point in the search for low-cost transportation sector emissions reductions. Natural gas is abundant, easy to transport, and burns more cleanly than other hydrocarbons. Trucks switching to natural gas from diesel could reduce their emissions by up to 30%.[1][2]
  - ✓ A medium/heavy-duty truck powered by a natural gas engine has tailpipe NOx emissions that are comparable to – or lower than – the amount of NOx emitted to produce electricity used to charge a similar medium/heavy duty battery electric truck.
- Natural gas trucks offer the most cost-effective option to reduce carbon emissions. [2]
  - ✓ Reducing diesel truck emissions quickly is key to meeting clean air objectives, therefore it is imperative to achieve the maximum volume of emissions reductions possible for every dollar spent. Relative to battery electric, natural gas is 4x more cost effective at displacing diesel trucks and reducing overall emissions.
  - ✓ Natural gas trucks are road-tested, offer the power and performance that fleets require, and are available at a commercial scale from major manufacturers today. When looking across factors including range, fueling frequency and fueling speed, natural gas performs better than any other commercially available vehicle technology. [2]
  - ✓ Cummins has introduced a 15-liter natural gas engine capable of putting out 500hp and 1,850 lb. -ft. of torque and weighing about 500 lb. less than a 15-liter diesel. The 15-liter engine allows Canadian fleets operating with Class 8 trucks at the 140,000lb GVWR class to adopt natural gas.[3]

Renewable Natural Gas ("RNG") Integration Will Exceed Climate Targets

RNG is made primarily from organic waste, generated by a variety of sustainable and renewable resources, including wastewater treatment plants, food and green waste, landfills, dairies, farms and forest management.

- Using RNG enables fleets to go beyond carbon neutrality. RNG for transportation can reduce greenhouses emissions from natural gas by up to 283%, with an average of 51% reduction (varies by feedstock).[4]
- Production of large volumes of RNG can happen in Canada and the U.S. A 2019 ICF study found that by 2040 there will be 13 billion diesel gallon equivalent of RNG supply available annually in the U.S. in a low scenario, and as much as 32 billion diesel gallon equivalent available annually in a high scenario., meaning RNG could replace as much as 70% of the current U.S. on-road diesel use annually.[4]

Natural Gas Powertrain Tailwinds

1. Achieves ESG and Sustainability Goals
2. Least Commercially Disruptive for Long-Haul Heavy Duty
3. Next Best Infrastructure after Diesel
4. Suitable for Multi-Shift Operation
5. Stable Natural Gas Fuel Pricing
6. Improved Total Cost of Operations to Achieve Reduced GHGs.

For citations, please refer to "Sources" on page 13.

Compressed Natural Gas

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CNG is a Solution for Medium-Duty Vehicles Travelling Short Distances

Compressed natural gas ("CNG") is produced by compressing natural gas to less than 1% of its volume at standard atmospheric pressure. To provide adequate driving range for transportation, CNG is stored aboard a vehicle in a compressed gaseous state at a pressure of up to 3,600 psi.

- CNG is typically used for fueling medium-duty vehicles travelling short distances, like a city bus or a garbage truck.[1]
- The reason CNG is used for short distances is that to hold an equivalent amount of fuel, CNG tanks need to be ~4 times larger than diesel tanks, which reduces the practicality of CNG fuel for larger distances.[1]
  - ✓ CNG has an energy density of 215 kg/m^3, while diesel has an energy density of 836 kg/m^3.[1][2]
- There are two types of CNG fueling stations:
  - ✓ Fast-fill stations: Fast fill stations receive natural gas from a pipeline, compress it onsite, and move it to storage vessels. These stations allow filling of a vehicle quickly with the help of specialized dispensers. To be effective, Fast-fill stations require adequate electrical capacity for compression and proximity to gas pipelines; and
  - ✓ Time-fill stations: Time-fill stations deliver CNG at a lower pressure than a fast-fill setup and no not use storage vessels. These stations use large compressors to fuel vehicles over a long period of time compared to fast-fill and are ideal for commercial vehicle fleets to use for overnight fueling.
- Hybrid fueling stations utilizing LNG to produce CNG, called LCNG fueling stations, are another fueling option which provide benefits over conventional CNG fueling stations.[3]
  - ✓ LCNG fueling can accommodate both CNG and LNG and provides economic fueling for CNG in areas not proximate to pipelines;
  - ✓ Since LNG is pretreated before liquefaction to remove contaminates, LCNG is cleaner than CNG, which will reduce the contamination and corrosion to vehicle equipment; and
  - ✓ LCNG stations require less energy and smaller capital investments than CNG stations while still meeting fast refueling needs.
- CNG has already been established in many North American cities as an attractive option to lower emissions in urban transport systems and delivery trucks, and while CNG adoption will likely continue in these urban markets, the constraints on range and cargo space due to tank size and weight as well as costs associated with fill time make it unsuitable for Class 8 long-haul trucking.

Purchase Price (MSRP)[4]

$262,000

Fuel Cost[5]

$3.3/GGE

Driving Range[1]

450km

Operating & Maintenance Cost[4]

$0.12-$0.24/km

Time to Refuel[4]

10 min

Payload Capacity[4]

~50,000lbs

Carbon Intensity[6]

67gCO_2eq/MJ

For citations, please refer to "Sources (Cont.)" on page 14.

Liquefied Natural Gas

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LNG Meets Heavy-Duty Long-Haul Performance and Cost Needs

Liquified Natural Gas ("LNG") reduces the volume of natural gas by approximately 600 times, and LNG as a fuel has many advantages over CNG:

- The most significant difference between LNG and CNG is energy density. LNG has a density of 466 kg/m^3 at -162°C at atmospheric pressure, while CNG has a density of 215 kg/m^3 at a pressure of ~3,600psi and room temperature; meaning LNG energy density is 2.4 times higher than CNG. This makes LNG the better fuel when it comes to larger vehicles, and vehicles that travel long distances.[1]
- The weight differences between LNG and CNG are also significant, LNG is about 400 pounds per 135-gallon diesel storage. CNG is 2000 pounds per 135-gallon diesel storage. [2]
- The liquid state of LNG allows a flow similar to the flow of diesel fuel, resulting in faster refueling of a truck than CNG. In terms of energy content, ~1.7 gallons of LNG is equivalent to 1 gallon of diesel, allowing for much larger quantities of fuel onboard a Class 8 truck without constraints on load size or truck reconfiguration. [1]
- Fuel prices allow LNG powertrains to be extremely cost-competitive with diesel, despite the higher initial purchase cost and are most cost effective as quickly as after 2 years, without factoring in climate incentives/penalties for diesel, or current diesel prices.[1]

Infrastructure Considerations

LNG adoption in Canada and the U.S. has been limited due to a lack of fueling infrastructure to support fleets. Relative to other proposed alternative fuels however, development of an LNG fueling network for Class 8 long-haul trucking is quite feasible within a short timeframe, as demonstrated by adoption rates in Europe.

- According to NGVA Europe, the European continent now has 4,000 CNG and 400 LNG stations in it fueling network, and about 300 new CNG stations achieved commercial operations in the last year, a growth rate of 8.1%. At the same time, the number of LNG stations grew from 250 to 400, an increase of 60% that reflects a huge gain in the number of new LNG vehicles. [3]
- Unlike CNG refueling infrastructure, which needs to be located proximate to pipeline gas supply and supplied with adequate electrical capacity, LNG fueling stations can be located anywhere or even mobile, allowing for flexibility of transport routes for heavy-duty LNG vehicles.

LNG powertrains are the closest direct replacement for diesel powertrains in terms of operational performance and cost effectiveness. Switching to LNG would allow the transportation sector to meet and even exceed climate targets, making it the logical choice for the next generation of Class 8 long-haul trucking in both Canada and the U.S.

Purchase Price (MSRP) [4]

$278,000

Fuel Cost [5]

$3.6/GGE

Driving Range[1]

1200km

Operating & Maintenance Cost[6]

$0.12-$0.24/km

Time to Refuel[4]

5-10min

Payload Capacity[4]

~50,000lbs

Carbon Intensity[7]

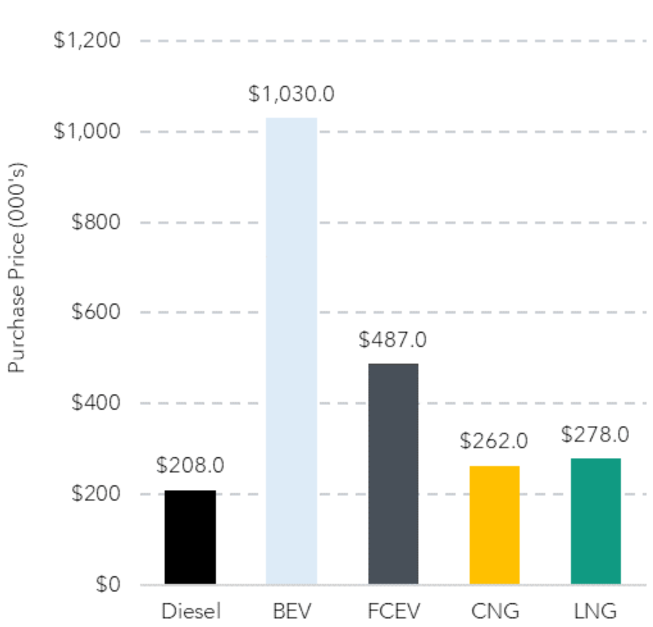
77gCO_2eq/MJ

LNG is the Best Market-Ready Alternative Fuel for Class 8 Long Haul

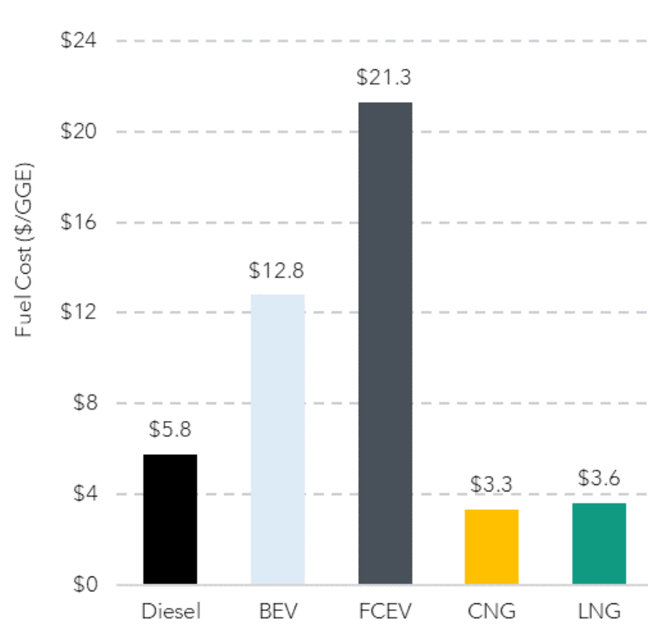
For trucking fleets looking to transition from diesel to a lower carbon intensity fuel, LNG powertrains are the best market-ready choice:

- Battery Electric powertrains require significant innovation in battery energy density and charging rates before being a suitable option for trucking fleets. Current observed electricity prices for light-duty vehicles are simply uneconomic for heavy duty transport. Until the assumptions in the NREL ultimate scenario can be met, battery electric powertrains may be best for shorter-range applications (first and last mile trucking);
- Hydrogen fuel cell powertrains require significant reductions in fuel cost, operating and maintenance cost, and hydrogen storage cost, as well as innovations in hydrogen distribution and fueling before fuel cell powered trucks can achieve a total cost of ownership competitive with diesel or natural gas powertrains. For hydrogen, achieving ultimate scenario fuel costs is critical to becoming competitive in class 8 long haul markets;
  - ✓ For both battery electric and hydrogen, a lack of refueling infrastructure is a major obstacle to adoption, and both technologies require significant refueling innovation before an infrastructure rollout strategy could be contemplated.
- CNG presents the best choice for class 8 short haul and class 4 parcel delivery, and successful adoption of CNG vehicles in cities is demonstrated by buses and garbage trucks where shorter distances and the ability to utilize slow fill refueling compliment CNG well; and
- The introduction of the Cummins 15-Liter natural gas engine for heavy-duty trucks in 2021 solidifies the case for LNG adoption in class 8 long haul trucking. With 500hp and 1,850 ft-lbs of torque, LNG powertrains with the Cummins 15L engines can offer the range and performance required by a long-haul trucking fleet, while also lowering fuel costs and carbon intensity. When powered with RNG, the powertrain can achieve net zero or even negative emissions. Although LNG refueling infrastructure in Canada and North America is limited, the abundance of natural gas and existing pipeline infrastructure supports a quick transition to LNG adoption, as demonstrated by LNG growth rates in Europe.

Purchase Price[1]



Fuel Cost[2]



For citations, please refer to "Sources (Cont.)" on page 14.

Summary (Cont.)

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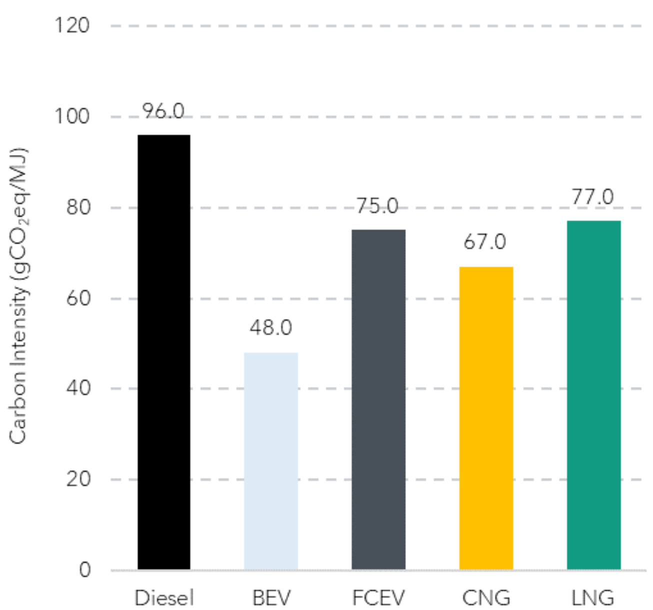
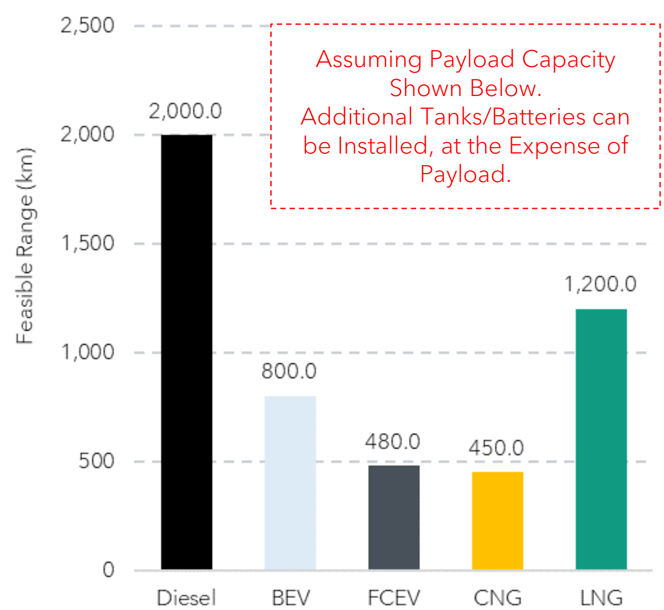
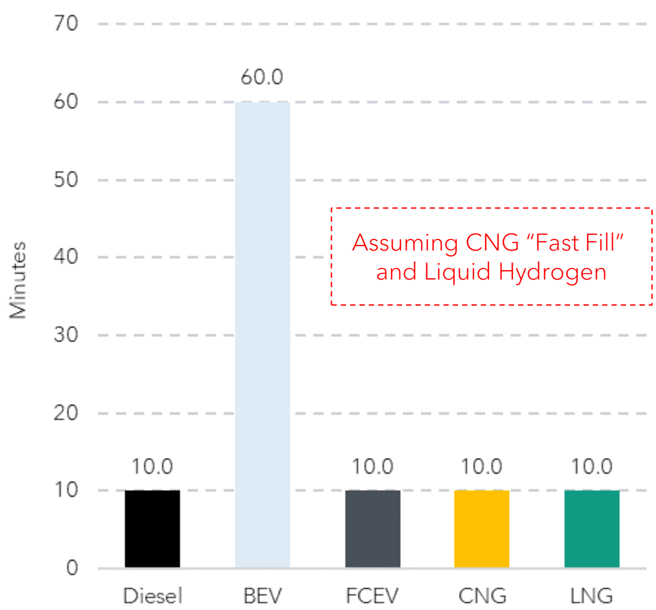
Carbon Intensity - Canadian Average[3]



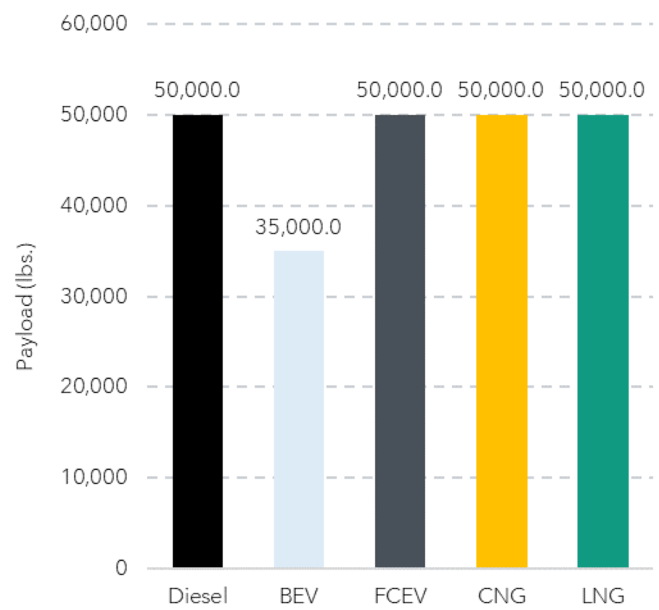
Driving Range[4]



Time to Refuel[5]



Payload Capacity[6]



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Compressed Natural Gas

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3. As per cowest.com "Get To Know THE LCNG Fueling Station", November 2016. (https://cowest.net/get-to-know-the-lcng-fueling-station/)
4. As per the NREL, "Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks", September 2021.
5. As per the U.S. DOE, "Clean Cities Alternative Fuel Price Report", April 2022.
6. As per the Government of Canada, "Milestone 2: Methodology for Fossil Fuel Pathways and Baseline Carbon Intensities", March 2020.

Liquefied Natural Gas

1. Smajla I, Karasalihović Sedlar D, Drljača B, Jukić L. Fuel Switch to LNG in Heavy Truck Traffic. Energies. 2019; 12(3):515. https://doi.org/10.3390/en12030515
2. As per Pioneer LNG. "LNG VS. CNG – ADVANTAGES & DISADVANTAGES" (https://www.pioneerlng.com/lng-vs-cng/).
3. As per NCVA Europe, "EU Rapidly Expanding CNG, LNG Fueling Network" (https://ngtnews.com/ngva-europe-eu-rapidly-expanding-cng-lng-fueling-network).
4. As Per Hyliion Hypertruck ERX (https://www.sec.gov/Archives/edgar/data/1759631/000121390020015311/ea123187ex99-3_tortoiseacq.htm).
5. As per the U.S. DOE, "Clean Cities Alternative Fuel Price Report", April 2022.
6. Estimate as per NREL, "Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks", September 2021
7. As per the Government of Canada, "Milestone 2: Methodology for Fossil Fuel Pathways and Baseline Carbon Intensities", March 2020.

Summary

1. As per NREL (Diesel, BEV, FCEV, CNG) and Hyliion Hypertruck ERX (LNG)
2. As per GlobalPetrolPrices.com (Diesel), NREL (BEV), and the U.S. DOE, (Hydrogen, CNG, LNG)
3. As per the Government of Canada, "Milestone 2: Methodology for Fossil Fuel Pathways and Baseline Carbon Intensities", March 2020.
4. As per NREL (BEV), the Hydrogen and Fuel Cell Technologies Office, (Hydrogen). and Smajla I, Karasalihović Sedlar D, Drljača B, Jukić L. Fuel Switch to LNG in Heavy Truck Traffic. Energies. 2019; 12(3):515. https://doi.org/10.3390/en12030515 (CNG, LNG).
5. As per NREL (Diesel, Battery Electric, Hydrogen, CNG) and Hyliion Hypertruck ERX (LNG).
6. As per NREL (Diesel, Battery Electric, Hydrogen, CNG) and Hyliion Hypertruck ERX (LNG).