IS NATURAL GAS FINALLY ACCELERATING AS A TRANSPORTATION FUEL?

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Introduction

A number of recent projections have identified the potential for natural gas to gain market share via a phase of rapid growth which will see it become the alternative fuel of choice in a range of transportation applications (see ACT Research, National Petroleum Council, Frost & Sullivan in Figure 5). While natural gas has a long history of global transportation use, a number of recent developments including technological advances, compelling fuel price differentials and forward-thinking policy from regulators have altered the playing field and strengthened the value proposition for natural gas.

One of the best examples of this is the rapid adoption of natural gas fuelled vehicles in the North American refuse truck market where the share of new vehicle sales has increased from 10 per cent to nearly 50 per cent in three years. Similar conditions to those underlying the success of natural gas in the refuse sector exist for heavy-duty trucking, rail, marine and mine-haul applications, with each market presenting opportunity for the displacement of petroleum-derived fuels.

This paper will explore the history and recent developments of natural gas as a transportation fuel for heavy-duty on-road and off-road applications, with a particular focus on the evolving factors which have strengthened its prospects for transitioning from a niche to mainstream.

Background – Historical Barriers to Natural Gas as a Transportation Fuel

Despite its history as a transportation fuel, the widespread adoption of natural gas has been impeded by a number of market barriers. The primary challenges have not been related to technology but rather with the economics when compared against established incumbent fuels and engines. Cost hurdles for natural gas vehicles include cost premiums on engine and vehicle fuel storage, refuelling infrastructure related expenses for the provision of sufficient network coverage for typical fleet use, as well as price instability associated with the fuel itself.[1] This section will describe the obstacles to the uptake of natural gas vehicles as an introduction to the recent changes that have enabled NGV populations to achieve growing market share.

a) Engine cost

Competitive pricing of alternative engine technologies against established products is the primary obstacle for any new market entrant, and historically has been a key determinant of the slow uptake of natural gas vehicles in many markets (National Petroleum Council, 2012). Where factory-built OEM natural gas vehicle products have been available, the lower volume of production has hampered the effect of economy of scale that could keep costs in-line with competing products (Ibid.).

b) Fuel distribution and dispensing infrastructure

Sufficient coverage of fueling infrastructure is another obstacle common to alternative fueled vehicle technologies. Applications such as inter- and intra-city on-road freight shipping have struggled to attain a

[1] Sufficient refuelling infrastructure coverage is commonly estimated at 30 per cent of existing conventional fueling coverage. For more information, see National Petroleum Council Future Transport Fuels Study, Natural Gas Chapter section ‘Considerations for Fueling Infrastructure’.

level of coverage necessary for these commercial applications (Melaina and Bremson, 2008). Return-to-base-fleets have had success with implementing their own private fueling stations; however, typical installation costs for natural gas fueling stations, whether compressed or liquefied gas, have been higher than those typical of gasoline or diesel fuels. In the case of liquefied natural gas (LNG), the finite holding time of gas in a liquefied state imposes additional restrictions on vehicle range and has the potential to necessitate additional infrastructure build-out.

c) Retail and commodity fuel price instability

Historically the price of natural gas has not exhibited the same stability as gasoline or diesel due to the lack of a unified global commodity market as well as the variety of competing non-transportation uses. Natural gas has been subject to fluctuating competing demands from industrial, heating, and power generation end uses, which can vary greatly from year-to-year, presenting challenges to the ability of fuel buyers to accurately budget and predict future fuel costs (EIA 2007).

Transition Fundamentals

Diesel and gasoline continue to power 99 per cent of global transportation, but some fundamental conditions have accelerated the growth of natural gas as an alternative fuel. Significant advancements in upstream extraction technology have enabled vast new reserves of gas, exerting a sustained downward pressure on fuel prices and the potential for price stability. At the same time, natural gas has emerged as a viable option to challenges of price volatility, air quality and energy security.

a) Fuel price and availability

The advent of hydraulic fracturing in combination with horizontal drilling has greatly improved the recoverability of both gas and liquid fossil fuels. Despite the application of these techniques to a variety of energy extraction activities, including natural gas, petroleum, and geothermal power, the net impact on commodity energy prices has been uniquely transformational for natural gas (Bipartisan Policy Center, 2013). The glut of production in North America has been sufficient to reverse the flow of developing international gas movements, converting liquefied natural gas import terminals into export terminals and for the first time seriously approaching an active and integrated international and intercontinental trade in LNG (Deloitte, 2013).

The effect of this newfound gas supply has been to flatten prices for the immediate and foreseeable future, granting fleet managers confidence in their payback periods for new vehicles and ensuring a stable and affordable supply at the same time as conventional fuel prices are experiencing greater upward price pressure (Figure 1).

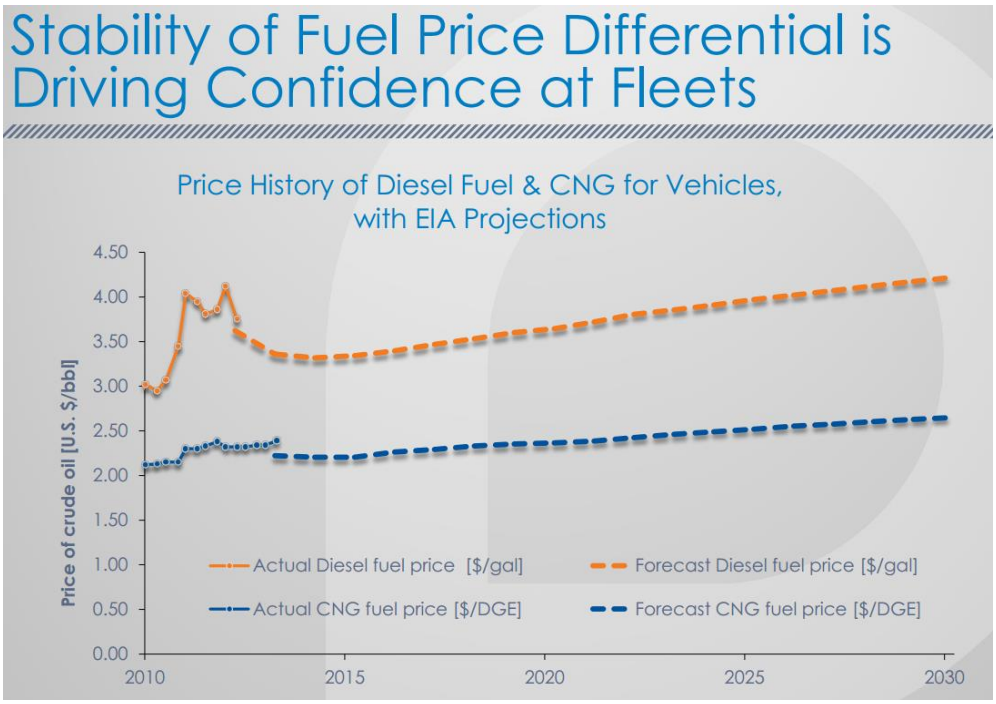

Figure 1: Present and Forecast Fuel Price Differential (EIA Projections)

b) Policy support for natural gas vehicles

Policy makers and regulatory agencies in many jurisdictions have converged around natural gas as a favoured solution to the environmental, economic, and fuel security impacts of conventional fuels. Notable policy developments are supporting growing natural gas vehicle populations in the United States, the European Union, and China.

In the United States, direct policy support for natural gas vehicles and stations has developed primarily at the state level, with support varying from state to state. Almost all states have passed laws directly targeting natural gas vehicles, and seven leading states have over 10 such laws in place (Alternative Fuels Data Center, 2013).[2]

Within the European Union, a region-wide initiative called 'LNG Blue Corridors' has seen 27 partners from 11 countries invest 14.33 M€ in a four year effort that aims to create sufficient infrastructure for LNG long-haul trucking to move goods across the region (NGVA Europe, 2013).

The Chinese government has given prominent support to natural gas vehicles in recent years as a preferred solution to severe air pollution problems across the country. In 2012, the national gas use policy was revised to give priority use to natural gas in transport applications for the first time (Interfax, 2014). This policy change expanded the number of 'preferred' users of natural gas to include many classes of transport applications, as well as incentivizing the construction of supporting refueling infrastructure.

c) Infrastructure build-out

[2] California, Arizona, Utah, Texas, Oklahoma, Indiana and Virginia all have over ten policy mechanisms specifically targeting natural gas vehicles.

Infrastructure supporting natural gas vehicle populations is projected to grow steadily around the world (Navigant, 2013). The European Commission is laying the groundwork for international LNG powered freight transport through the Blue Corridors project, and in the U.S. private entities such as Clean Energy Fuels, Shell and Blu Transfuels have committed to building-out highway infrastructure to enable long-distance trips without the challenge of range-anxiety.

Historic Transitions: From Alternative to Mainstream Energy

Natural gas is considered an alternative fuel with an engaged industry creating the technical innovations and components to expand and enable markets and demand. One path to market in this industry is through components and after-market conversions to stimulate interest and prove the technology. As markets become more defined and demand grows, innovative components and products will become integrated at the OEM level, at which point mainstream adoption is most likely to occur as customer costs are expected to decrease, and engines and fuel systems are produced at higher quality and quantity (Figure 2).

Figure 2: Market Transition (Westport Corporate Update, 2014)

Natural gas is well positioned to be a mainstream transportation fuel of the future. The combination of the historical shift of energy sources in the transportation and rail industries provide example cases that can help identify future opportunities and markets.

a) Historic Transitions - Rail

The rail industry in North America is comprised of seven dominant operators [3] and has experienced a variety of changes over time as transportation needs and rail use evolve (Kemp, 2014). Two shifts in energy supply: emergence of diesel as a mainstream fuel, and the implementation of electrical powered locomotives help highlight some of the successes and challenges of previous energy shifts.

Diesel-electric Direct Current (DC) systems replaced steam to power locomotives as a mainstream fuel between approximately 1941 and 1961 (Chase, 2014).

[3] Canadian National, Canadian Pacific, BNSF Railway, CSX Transportation, Kansas City Southern, Norfolk Southern, and Union Pacific

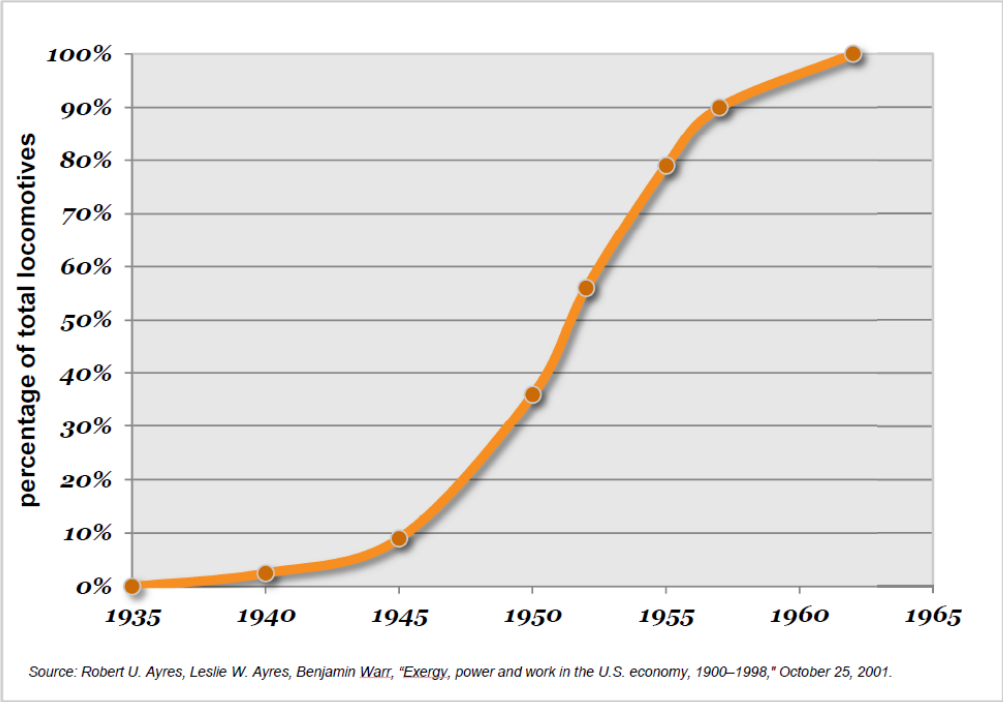

Figure 3: Diesel Powered Locomotives, North America (Ayres et al. 2001)

The primary driver of the shift was performance. As the demand for higher power engines arose, electricity generated by diesel was quickly identified as a more efficient, energy-rich fuel than steam (coal) power. Electro-diesel locomotives offered a 39 per cent operational cost savings per mile (Churella, 1998) which was sufficient to overcome the necessary capital investment required to change fuel supply infrastructure. The electro-diesel technology also created operational efficiencies over steam alternatives as there were fewer people required to operate, shorter refueling times, and a significant reduction in cool down/warm up time and cost (Kemp, 2014).

Today, commercial locomotives run on DC, Alternating Current (AC), or Diesel- electric engines. The adoption of AC engines and electric power began in the 1970's and is a result of further market development and segmentation due to expanded use and evolving customer needs. AC current provides increased traction, power, and torque which are beneficial for some segments; and electric power is preferable in high traffic locations where power line installation is justified (Chase, 2014).

The history of fuel and power supply in the rail industry shows a capacity to implement large infrastructure investment/changes, diversifying product range based on segment development, and the ability to adopt innovation. We cannot ignore other attributes of the rail industry that influenced this change (competitive landscape, operation costs and fuel consumption, assets and investment in infrastructure, and development of environmental ideologies); however the widespread adoption of a new mainstream fuel source adoption is of value to understand how a fuel transition could happen.

b) Historic Transitions – North American Refuse Sector

The refuse sector of the North American Heavy Duty (HD) trucking industry contains early and rapid adopters of natural gas. There are a variety of unique attributes and needs of this segment that have enabled and supported this adoption (Blomerus, 2013).

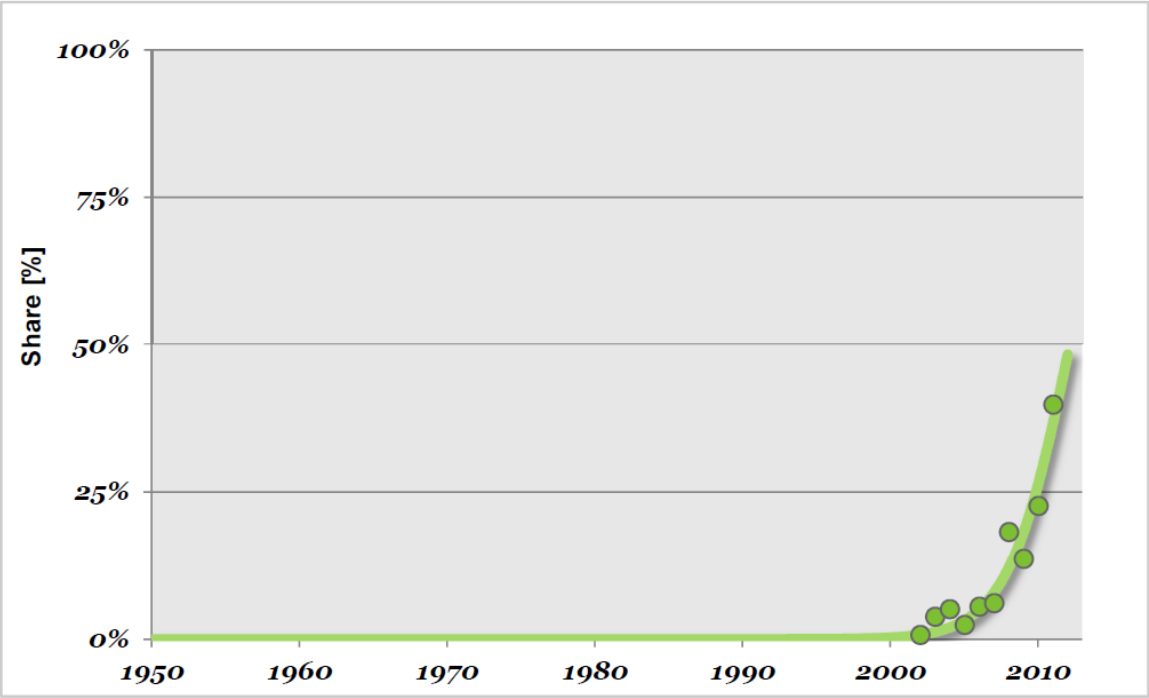

Figure 4: Market share of new natural gas refuse truck sales in the US (Blomerus, 2013)

Natural gas is an attractive fuel alternative for HD trucking as engine innovations and on-board fueling systems have created sustainable fuel cost savings relative to existing diesel options. One of the barriers to adoption is the availability of fuel, which is commonly measured by station locations and proximity to consumption and re-fueling points. A key attribute of the refuse trucking industry that has enabled adoption is the *return-to-base* nature of fleets, which overcomes the fuel availability challenges as trucks can re-fuel in their yard at the end of shifts (Truck News, 2014). This is an example of effective scale, as fuel demand is concentrated enough to justify the costs of private re-fueling infrastructure.

Adoption of natural gas in this industry is measured by market share of new truck purchases. The rapid growth and adoption shown in Figure 4 are the result of the influence of two dominant industry players (representing ~50% of the entire North American refuse collection market) who have realized efficiencies (Waste Management, Groupe EDI, Republic Services). Natural gas growth in the refuse segment has been driven by the oligopoly market structure, high cost-saving potential, and consistency of demand. We believe that early adopters are crucial to generate sufficient interest, initial momentum, and demand to influence others (with increasing ease) to overcome various barriers to mainstream success.

Identification of Market Attractiveness

Historical adoptions of fueling alternatives have been driven by operational improvements and changing needs. Supply of domestic and international natural gas is growing as innovations in extraction, processing, and transportation are adopted by the industry (Bipartisan Policy Center, 2013). One of the major changes in the needs of customers has been related to emissions and the environmental impact of fossil fuel dependency, which was not considered when the trucking industry shifted from gasoline to the cheaper and 'dirtier' diesel between ~1930-1970 (ACT Research, 2012). Natural gas is widely accepted as a cleaner burning fuel than diesel, and additionally is in far greater local supply than the majority of other clean-burning alternative fuels (biodiesel, ethanol blends, electricity/solar) (Staple, 2013). In addition to supply benefits, natural gas vehicles offer significant emission reduction over existing diesel engine options. The National Petroleum Council (2012) has quantified the emissions reduction associated

with using natural gas for transportation to be in the range of 11-25 per cent, in comparison with diesel and gasoline.

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a) Opportunity Identification – Heavy Duty, On-Road Trucking

The largest consumers of diesel fuel may realize the greatest potential savings and be the most capable of absorbing some investment in adoption of an alternative fuel. Heavy Duty trucking (Class 7&8) consumes approximately 20 per cent of the fuel (US Department of Energy), and 60 per cent of the diesel in the United States (Vanderklippe, 2013) creating an attractive concentrated segment of the transportation energy market.

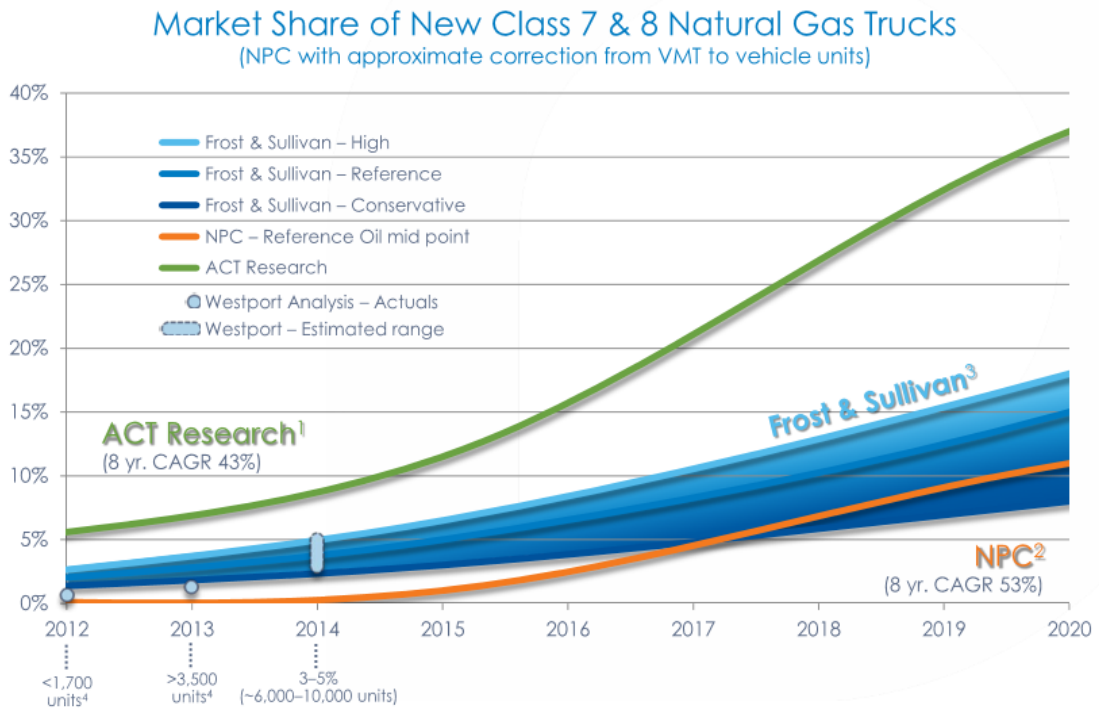

Figure 5: Market share of New Class 7&8 Natural Gas Trucks (Westport Corporate Update, 2014)

The earlier-cited projections from NPC, Frost and Sullivan, and ACT Research show that market share of new sales of HD natural gas trucks in North America may be between 10 per cent and 25 per cent by 2018. The high mileage and rapid turnover of the HD fleet as compared to the light-duty vehicle population mean that the potential for adoption is increased (Staple, 2013). The combination of these attributes creates significant market potential, as HD adoption can be the tipping point for a fuel shift across the entire transportation industry.

Long haul applications will likely experience the greatest barriers to adoption as these fleets require a re-fueling network that serves a broad highway system. It is easy to see that as sales to early adopters grow, the demand (and opportunity) for on-road fueling alternatives will follow. In North America, fuel supply companies including Clean Energy, Blu LNG, and Shell have identified the opportunity to work with fleets to enable natural gas refueling options during the transition period in transportation fuel.

b) Opportunity Identification – High Horsepower Markets

Apart from HD trucking, which consumes approximately 20 per cent of fuel or 40 billion gallons of diesel annually (federal Highway Administration, 2003), four other industries are high consumers of diesel (Figure 9). Each of these industries represents smaller concentrated segments of the transportation fuel

market that has attractive attributes relative to natural gas adoption and rail and marine are particularly compelling. A brief overview of industry attributes and a SWOT analysis is provided.

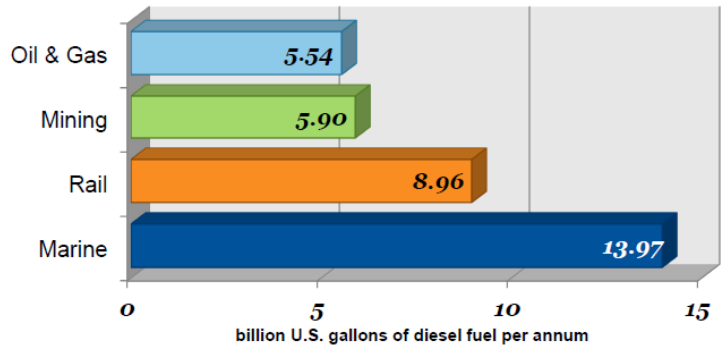

Figure 6: Global diesel consumption in demanding high horsepower applications (UN Energy Statistics Database, Westport Analysis)

a. Rail

- The rail industry consumes 7per cent of the diesel used in the U.S. on a daily basis, which accounts for approximately one quarter of the operating expenses of the major rail companies (EIA Annual Energy Outlook, 2014);
- The competitive landscape of the rail industry is dominated by seven Class 1 companies with two companies (BNSF and Union Pacific) representing approximately 63 per cent of the diesel consumption by rail in North America (Chase, 2014). This oligopoly, which requires high capital investment, is attractive if operational efficiencies can be created through technological innovation.
- Fuel sources have historically changed in this industry and overcome similar barriers that exist in the current market (infrastructure development, fleet turnover, adoption).

Strengths	**Weaknesses**
➢ High fuel consumption creates high potential savings given current price projections. ➢ Potential for rapid adoption due to lack of small number of market players. ➢ Industry has history of rapid adoption.	➢ Long-life of locomotives limits fleet turnover and opportunity for change. ➢ High cost of assets and required infrastructure (refueling) for adoption.
Opportunities	**Threats**
➢ Duopoly of locomotive manufacturers in North America. ➢ Increased domestic production of natural gas. ➢ Significant existing capital investments (primarily tracks) by operators represent integrated organizations motivated to operate efficiently.	➢ Implementing changes in a highly regulated industry relating to fuel storage, and emissions could influence innovations. ➢ High opportunity for first-mover advantage, thereby creating a risk for the second mover in a duopoly. ➢ Competition from other fuels or innovations in diesel engines.

b. Marine

- The marine industry is a large global consumer of diesel fuel in operations.

- Multiple segments of the industry exist including trans-oceanic, and return-to-port operations, may represent a potential path-to-market similar to what was observed in the North American refuse truck segment (described earlier).
- Development of the global natural gas market hinges on the ability to transport natural gas by sea to international markets, creating an opportunity for re-fueling availability in ports.

Strengths	**Weaknesses**
➢ High fuel consumption creates high potential savings given current price projections. ➢ Multiple market segments increase potential for adoption (return-to-port). ➢ Global fuel distribution network will help to overcome fuel availability challenges.	➢ Technical challenges of converting existing on-board fuel storage capacity to high pressure natural gas tanks. ➢ Global fuel availability is required as dual fuel options will impact competitive advantage of natural gas, as more on-board space would be required for fuel availability. ➢ High potential cost of conversion.
Opportunities	**Threats**
➢ Sea vessels have a long life span, and often out-last engines, therefore creating an opportunity to convert existing fleets. ➢ Development of global market and distribution could influence adoption: natural gas tankers should run on natural gas.	➢ Implementing changes in a highly regulated industry relating to fuel storage, and emissions could influence innovations. ➢ Natural gas adoption in the marine market has begun in some geographies, indicating that a competitive market is in development. ➢ Competition from other fuels or innovations in diesel engines.

Summary

Natural gas is well positioned for growth based on the convergence of attractive features in market segments driven by changes in energy supply, demand, and price. Along the transition to a mainstream fuel, natural gas is being accelerated due to OEM investments in technology, emerging regulatory certainty and industry efforts to build and stimulate markets.

Part of our confidence in natural gas for the global (or just North American) transportation market is driven by the potential we see in HD trucking and high horsepower applications such as rail, and marine. Historic transitions and shifts in similar industries have helped to identify indicative attributes of favourable adoption of alternative fuel sources. It is known that changes in fuel sources will be driven primarily by opportunities for cost savings. Going forward, the fundamental market conditions in the rail industry to facilitate another change in fuel source, and demand for marine applications will increase based on infrastructure and global market developments.

We believe that the future is bright for natural gas in the transportation fuel industry. There are numerous paths to market adoption and growth that can be capitalized on, given the right combination of innovation and opportunity identification.

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