HEAVY-DUTY DIESEL VEHICLES: THEIR CARBON-CONSTRAINED FUTURE ROLE WITHIN THE NORTH AMERICAN ECONOMY
HEAVY-DUTY DIESEL VEHICLES: THEIR CARBON-CONSTRAINED FUTURE ROLE WITHIN THE NORTH AMERICAN ECONOMY
Heavy-Duty Diesel Vehicles: Their Carbon-constrained Future
Role Within the North American Economy

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Author: Jon Rozhon

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Canada
www.ceri.ca

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Executive Summary

This study grew out of CERI’s Natural Gas Pathways project, which examines potential future North American natural gas usage throughout the economy, including for transportation. In the course of our research for that project, it soon became clear that Natural Gas Vehicles (NGV’s) would not likely move beyond niche status within the transportation sector – even under an assumption of long-term, low cost, ample, domestic natural gas availability. The reasons for this are varied but include a long-standing and massive shipping and refueling infrastructure built around heavy-duty diesel vehicles and the continuing ready availability of low-cost crude-based fuels.

The bigger story turned out to be the future of North American heavy-duty trucks, a vehicle category that consumes more than 2.5 million barrels per day (MMBPD) of diesel fuel. These vehicles have long been major fuel consumers, and over the past half century have seen many market-driven technological innovations to improve fuel economy, safety, power, drivability, and reliability. But in 2011, the US Federal government announced new emissions and fuel standards for heavy-duty diesel vehicles – the first such standards in history – aimed at squeezing optimal environmental performance out of all new vehicles manufactured between 2014-2020. In 2013, the Canadian government followed suit, stating they would adapt almost identical standards. What would these standards mean for the trucking industry? In what way would they lessen emissions: through improving environmental performance or through limiting growth of the trucking industry or through some combination of the two?

For the Natural Gas Pathways project, CERI, along with ICF Marbek, whatif? Technologies, and Scenarios to Strategy, Inc. developed four narratives\(^1\) exploring different directions for the future of the North American natural gas industry. Each narrative considers the natural gas industry within the larger context of the energy sector (oil, coal, renewables, etc.); the narratives are also broad enough in scope to draw conclusions on transportation growth patterns in general and the heavy-duty diesel vehicle category specifically. Those conclusions are charted and discussed within this study.

Besides applying the new mileage and emissions standards in our model, we assume that truck industry growth tracks GDP. We also utilize past trends in average distance traveled and fuel usage in projecting future trends in these areas. Among this study’s findings are the following:

- Projected US heavy-duty diesel vehicle number growth over the next 20 years falls within a range of 459,000 and 3,602,000 vehicles (see Table E.1 and Figure 5 on page 9).

---

\(^1\) These narratives are titled as follows: Nowhere Fast, Power Wave, LNG Tsunami, and Full Speed Ahead. For an overview of each narrative, see Appendix A.
Table E.1: Projected Total Number of Licensed US Heavy-Duty Vehicles to 2030

<table>
<thead>
<tr>
<th>CERI Narrative</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Speed Ahead</td>
<td>4,956,416</td>
<td>5,403,702</td>
<td>6,243,715</td>
<td>7,276,188</td>
<td>8,558,655</td>
</tr>
<tr>
<td>LNG Tsunami</td>
<td>4,956,416</td>
<td>5,340,960</td>
<td>6,072,341</td>
<td>6,903,876</td>
<td>7,849,279</td>
</tr>
<tr>
<td>Nowhere Fast</td>
<td>4,956,416</td>
<td>4,650,377</td>
<td>4,648,223</td>
<td>4,928,862</td>
<td>5,415,238</td>
</tr>
</tbody>
</table>

Source: CERI

- Projected Canadian heavy-duty diesel vehicle number growth over the next 20 years falls within a range of 11,300 and 427,000 vehicles (see Table E.2 and Figure 11 on page 14).

Table E.2: Projected Total Number of Licensed Canadian Heavy-Duty Vehicles to 2030

<table>
<thead>
<tr>
<th>CERI Narrative</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Speed Ahead</td>
<td>630,868</td>
<td>677,167</td>
<td>782,433</td>
<td>909,699</td>
<td>1,057,666</td>
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<tr>
<td>LNG Tsunami</td>
<td>630,868</td>
<td>669,304</td>
<td>760,957</td>
<td>865,161</td>
<td>983,635</td>
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<tr>
<td>Power Wave</td>
<td>630,868</td>
<td>643,589</td>
<td>698,445</td>
<td>765,373</td>
<td>838,715</td>
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<tr>
<td>Nowhere Fast</td>
<td>630,868</td>
<td>582,530</td>
<td>581,326</td>
<td>610,980</td>
<td>642,146</td>
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</table>

Source: CERI

- Projected US heavy-duty diesel fuel usage savings – as a result of new emissions and mileage standards – over the next 20 years fall within a range of 9 billion gallons and 14.3 billion gallons (see Table E.3 and Figures 6, 7, 8, 9, on pages 11-13).

Table E.3: Projected US Heavy-Duty Diesel Fuel Usage Savings to 2030 – Under New Standards

<table>
<thead>
<tr>
<th>CERI Narrative</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Speed Ahead</td>
<td>0</td>
<td>1,411,738,068</td>
<td>8,214,305,782</td>
<td>12,113,884,511</td>
<td>14,306,102,965</td>
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<tr>
<td>LNG Tsunami</td>
<td>0</td>
<td>1,395,346,508</td>
<td>7,988,844,657</td>
<td>11,494,033,791</td>
<td>13,120,354,920</td>
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<tr>
<td>Power Wave</td>
<td>0</td>
<td>1,334,605,912</td>
<td>7,139,268,464</td>
<td>9,931,843,351</td>
<td>11,096,088,588</td>
</tr>
<tr>
<td>Nowhere Fast</td>
<td>0</td>
<td>1,214,928,907</td>
<td>6,115,258,182</td>
<td>8,205,898,972</td>
<td>9,051,767,614</td>
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</table>

Source: CERI

- Projected Canadian heavy-duty diesel fuel usage savings – as a result of new emissions and mileage standards – over the next 20 years fall within a range of 941 million gallons and 1.7 billion gallons (see Table E.4 and Figures 12, 13, 14, 15 on pages 16-17).
Table E.4: Projected Canadian Heavy-Duty Diesel Fuel Usage Savings to 2030 – Under New Standards

<table>
<thead>
<tr>
<th>CERI Narrative</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Speed Ahead</td>
<td>0</td>
<td>169,455,742</td>
<td>984,198,397</td>
<td>1,448,597,629</td>
<td>1,690,965,592</td>
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<tr>
<td>LNG Tsunami</td>
<td>0</td>
<td>167,488,208</td>
<td>957,184,735</td>
<td>1,377,675,687</td>
<td>1,572,606,651</td>
</tr>
<tr>
<td>Power Wave</td>
<td>0</td>
<td>161,053,299</td>
<td>878,551,899</td>
<td>1,218,773,640</td>
<td>1,340,912,896</td>
</tr>
<tr>
<td>Nowhere Fast</td>
<td>0</td>
<td>135,735,942</td>
<td>651,872,517</td>
<td>879,852,664</td>
<td>941,844,311</td>
</tr>
</tbody>
</table>

Source: CERI

- None of the narratives point to a shift to alternative fuels. In both the US and Canada, transportation infrastructure is crude-based; all indications are that there will be abundant crude supply and means to refine it for decades to come.

- Natural Gas Vehicle growth over the coming 20 years is forecast to be negligible under all narratives but one. The most optimistic forecast, under the Full Speed Ahead narrative is for 864,000 NGV’s on US roads by 2030, consuming 6.4% of the diesel fuel total. This compares to 3.2% forecast in the Energy Information Administration’s (EIA) 2013 Annual Energy Outlook (Reference Case).²

---

² The EIA publishes 25 different scenarios besides the Reference Case. In the “High Oil Price” case, where oil reaches $237/barrel by 2040, natural gas takes a much larger role in the transportation sector, with usage as much as 25% of the diesel fuel total by 2030.
Introduction
Diesel-fuelled vehicles, long the transportation backbone for the North American economy, are set to remain at the centre of the continent’s shipping needs for many years to come. A look at present day petroleum product usage statistics shows that diesel fuel accounts for 20 percent of all refined petroleum product (RPP) consumption in the US, well over 3,000,000 BPD. In Canada, over 350,000 BPD is consumed. By far the most diesel fuel, over 70 percent, is burned by the largest vehicles on the road – heavy-duty diesel trucks, seen on highways from coast to coast. The North American economic system, with its numerous large container ports, complex, well-maintained highway system, and comprehensive vehicle refueling infrastructure, is designed for this kind of transport; as long as fuel prices remain relatively low, or until carbon constraints become economically onerous, highway transport will remain the preferred means of shipping goods throughout the continent.

Within this study, diesel vehicles are categorized as follows:

**Light-duty diesel vehicles**: These are cars and trucks with a gross vehicle weight (GVW) of 8,500 pounds or less. Most pick-up trucks, vans, and sports utility vehicles fall into this grouping. It is a small category – approximately 3 percent of all diesel fuel consumption – but set to grow significantly. European manufacturers, which have decades of experience manufacturing diesel sedans for their home markets, are introducing numerous new light-duty diesel vehicles to North America in 2013. This is being done not only to appeal to consumers hoping to save fuel costs, but also in the face of stiffening mileage and emissions standards.

**Medium-duty diesel vehicles**: This classification encompasses a wide variety of vehicles from 8,500 to 26,000 lbs. GVW, including school buses, single-axle vans, delivery trucks, and minibuses. Approximately 25 percent of all diesel fuel is consumed by medium-duty vehicles.

**Heavy-duty diesel vehicles**: All vehicles over 26,000 lbs. GVW fall into this category. These include dump trucks, garbage trucks, tour buses, high profile semis, and semi tractors. Heavy-duty diesel vehicles average well over 40,000 miles-traveled per year; light- and medium-duty vehicles, on the other hand, average under 20,000 miles-traveled per year. In the past, there have not been US federal government-mandated mileage or GHG emissions standards on the heavy-duty class of vehicles. However, the Administration announced in 2010 a Heavy-Duty National Program that will, for the first time in history, place these standards on all medium-

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5 There have been other emissions-related standards set in the past. For example, in 2006 the EPA legislated reduced sulfur content in diesel fuel, but this was done to mitigate the acid rain problem rather than to reduce GHG emissions.
and heavy-duty diesel vehicles, beginning with vehicles manufactured in 2014. The new rules were adapted in August 2011, through the joint efforts of the Environmental Protection Agency (EPA), which established the emissions standards, and the National Highway Traffic Safety Administration (NHTSA), which developed the fuel consumption standards. These new standards are accounted for in projections of diesel fuel usage within this study.

It should be noted that the Government of Canada, in its submission to the Copenhagen Accord on Climate Change, pledged to align its 2020 GHG emission goals with US goals. On February 25, 2013, the Federal Environment Department announced that Canada will follow US emissions and mileage standards for heavy-duty trucks. This study therefore assumes all future vehicle-related greenhouse gas and fuel efficiency rules or legislation announced by the US federal government and its agencies will be followed by similar rules or legislation in Canada.

**Change in the Heavy-Duty Vehicle Classification**

The heavy-duty diesel category, because it is far and away the largest of the three classifications and responsible for consumption of the most diesel fuel, is the focus of this study. And though this category is well established in North America, it will be facing considerable change in coming years. The only uncertainties lie in the nature and degree of that change. Heavy-duty diesel manufacturers have only ever been answerable to the marketplace, so while they have made strides in vehicle efficiency over the years, they have not been compelled to sacrifice the performance and power valued by clients for the mileage and emissions that are the concerns of government. The new standards, when implemented, should result in significant efficiencies gained, especially as the most easily attainable efficiencies are achieved in the early years.

Another change appearing on the horizon is the displacement of some diesel-powered heavy-duty trucks with natural gas-powered vehicles (NGV’s) or, more likely, the addition of NGV’s to the heavy-duty vehicle fleet. For several years, Texas oil and gas magnate T. Boone Pickens has been at the forefront of a movement to bring more NGV’s onto North American highways. Pickens has provided a geopolitical rationale for promoting natural gas over diesel – using a mainly domestic-produced energy source (natural gas) in place of a mostly overseas-supplied source (crude oil) would buttress the energy security position of the US, according to this line of thought. But there are other reasons why natural gas could one day claim a more considerable share of the heavy-duty vehicle category.

The technology is available: for example, Westport Innovations, a leading manufacturer of natural gas engines, has developed 12L and 15L natural gas engines appropriate for medium-

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and long-haul transportation applications; liquefied natural gas (LNG) and compressed natural gas (CNG) on vehicle fuel storage is also well-developed. The fuel is available: since shale gas resources became economical to develop, North American domestic natural gas supply has increased and production levels have been sustained. The fuel is cheap: on a gallon equivalent basis, approximately $1.50 less than diesel. Natural gas as a transport fuel is supported by legislators: in the American Taxpayer Relief Act that was enacted January 1, 2013 to avoid the “fiscal cliff”, the $.50/gallon tax credit for CNG and LNG were extended, as were tax breaks supporting natural gas refueling infrastructure; these credits were extended at a time when both the Senate and the House of Representatives were under significant pressure either to increase government revenues or cut government spending – an indication of the importance Congress today places on natural gas as a transportation fuel.

**Heavy-Duty Diesel Efficiency Measures**

For decades, since the Corporate Average Fuel Economy (CAFE) standards were first implemented in the US, gasoline-powered vehicles have been engineered to deliver better gas mileage and therefore emit fewer GHG’s per mile traveled. In the early years of CAFE standards, government was able to demand sharp increases in fuel economy for passenger cars, and many manufacturers met those standards (see Figure 1) as engineers were able to capture “low-hanging fruit”. This included replacing carburetors with fuel injection systems and moving away from less efficient 8-cylinder and inline-6 engines to V-6 engines that could fit in smaller automobile chassis.

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8 For a robust comparison of diesel vs. natural gas costs for heavy-duty vehicles, see the model available at [http://www.freightlinergreen.com/calculator](http://www.freightlinergreen.com/calculator) which takes into account numerous differences between natural gas and diesel, including diesel’s better thermal efficiency rate.

Similarly, as we enter the era of emissions and fuel mileage standards for heavy-duty diesel vehicles, the greatest efficiencies are expected to be seen in the early years, before the law of diminishing returns takes hold. In fact, the Administration provides a timeline of between 5 and 6 years to implement all of the standards. The new standards are far more complex than the early CAFE standards described above, as they vary depending on truck category, are in some cases optional for model year (MY) 2014, and also vary depending on payload. Manufacturers are provided with optional phase-in schedules — some being able to phase-in the standards by MY 2018 and others by MY 2019. Further, the heaviest diesels are subject to additional engine standards for fuel economy and GHG emissions. The standards are summed up by industry resource site www.dieselnet.com as follows:

- For combination tractors (the semi-trucks that typically pull trailers), the adopted engine and vehicle standards begin in MY 2014 and achieve from 7 to 20 percent reduction in CO₂ emissions and fuel consumption by MY 2017 over the 2010 baselines.

- For heavy-duty pickup trucks and vans, the standards phase-in starting in MY 2014 and achieve up to a 10 percent reduction in CO₂ emissions and fuel consumption for gasoline vehicles and 15 percent reduction for diesel vehicles by MY 2018.

- For vocational vehicles, the engine and vehicle standards start in MY 2014 and achieve up to a 10 percent reduction in fuel consumption and CO₂ emissions by MY 2017.¹¹


As in the early years of CAFE standards, the government is expecting significant and rapid efficiency improvements with the new standards. In which technological areas can these improvements be made? The National Academy of Sciences (NAS) was commissioned by Congress to examine this issue prior to new legislation being passed. The study revealed that fuel consumption reduction approaching 50 percent in most heavy-duty vehicle types is technologically feasible within the 5 years between 2015 and 2020, with improvements to be made in aerodynamics, weight, transmissions, fleet and vehicle management, engines, tires and wheels, and hybridization (see Figure 2).

Figure 2: Potential Fuel Consumption Improvement

Source: National Academy of Sciences

The NAS points to five distinct ways that fuel and GHG efficiency can be improved in long-haul, heavy-duty diesel trucks – the class of vehicles that consumes the vast majority of diesel fuel and is the focus of this study.

Aerodynamics: Vehicles that travel longer distances at highway speeds without stopping – such as Tractor Trailers (TT), coaches, Light Heavy-Duty (class 2b), and box trucks – benefit the most from aerodynamic alterations to improve drag coefficients. A typical tractor-trailer combination (one tractor and three trailers) with standard aerodynamic features can achieve fuel savings of between 10-15 percent with aerodynamic modification packages (fairings, aerodynamic mirrors, etc.) costing approximately $12,000. The fuel savings differ depending on duty cycle (how often the vehicle stops and starts) and the average speed of the vehicle in question.

**Engines:** Diesel engines, though already more fuel efficient than their gasoline equivalents, can still be improved considerably. NAS cites one manufacturer, Cummins Diesel that "has shown a roadmap for 49.1 percent thermal efficiency by 2016 and 52.9 percent by 2019, which are 14.5 percent and 20.6 percent reductions in fuel consumption, respectively, from a 2008 baseline." Technologies such as dual-stage turbocharging, turbo compounding (an additional turbine is added to the exhaust), common rail direct fuel injection, electrification of engine-driven accessories, advanced electronic engine controls, and improved emissions control devices can all be effective in improving efficiency of heavy-duty diesel engines. These technologies are all feasible today, with various manufacturers applying them to their vehicles.

**Hybridization:** Hybridization technology, which relies on hydraulics or batteries to store and release power to the vehicle, is especially effective in applications marked by shorter duty cycles (i.e., stop-and-start operations like transit buses and refuse trucks). Nevertheless, long-haul tractor trailers, which often need to stop and start as they move through urban areas, can see efficiency improvements approaching 10 percent (see Figure 2) through implementation of this technology.

**Tires:** Though rubber compounds, treads, and temperature all have an effect on rolling resistance, advances in other areas have been mainly responsible for the significant advances made in decreasing rolling resistance over the past 25 years. Much has been achieved through replacing tire pairs with wide-based single tires, and more improvement can be made if a greater percentage of the heavy-duty fleet were to be outfitted with these tires. Further efficiencies can be gained by the use of tire pressure monitoring systems and nitrogen-filled tires.

**Transmissions:** The difference in efficiency between manual transmissions, automated manual transmissions (AMT), and automatic transmissions (AT) may not be significant, depending on vehicle usage and the skill-level of the driver. However, in some cases, AMT's and AT's can help mileage and emissions noticeably. The newer transmissions feature "microprocessor technology to continuously monitor changes in road grade, vehicle speed, acceleration, torque demands, weight, and air resistance".

Other efficiency measures include idle reduction technologies and behavioral changes. There are several ways to reduce idling such as automatic shut-down, start-up systems and battery power systems; the degree of idling can vary depending on factors such as climate and season. As for behavioral changes, Figure 2 shows that proper driver coaching and management can

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13 Brown et al. P. 86
15 Brown et al. P. 66
bring as much as 5 percent greater efficiency in the Tractor Trailer class.\textsuperscript{16} And compared to many of the technological solutions, coaching and management comes at low cost.

If, as the NAS claims, fuel consumption and emissions reductions can be found in the range of 30 to 50 percent, why are the new standards demanding less from manufacturers? The simple answer is the higher standards come at a higher price. TIAX, a technology consultancy that assisted the NAS in the study, considered the costs and benefits of adapting various technologies for heavy-duty diesel vehicles. They found that technological changes costing between 0 and $20,000 per vehicle could see efficiencies exceeding 20 percent. Beyond the $20,000/20 percent threshold, returns diminish considerably (see Figure 3).

\textbf{Figure 3: Cost-Effectiveness of Fuel Consumption Improvement Technologies}

![Figure 3: Cost-Effectiveness of Fuel Consumption Improvement Technologies](image)

Source: TIAX\textsuperscript{17}

\textbf{US Heavy-Duty Diesel Vehicles}

In this study, we consider US regions according to the Petroleum Administration for Defense District (PADD), which is a categorization that has been used for energy data analysis purposes since World War II. The US regions with the most heavy-duty diesel registrations are all highly populated areas of the country, include key transportation hubs and corridors, and are usually home to at least one major seaport. As of 2011, the PADD area with the most registered heavy-duty vehicles in the US was PADD 2, with 40 percent (1,911,296 vehicles – see Figure 4). This

\textsuperscript{16} In Figure 2, management and coaching benefits are shown only for the Tractor Trailer class because that is the only vehicle type for which data and studies are available; the NAS notes that “other vehicle classes would also benefit from driver management and coaching…” P.4.

\textsuperscript{17} Jackson, Michael D. “Technologies to Improve Fuel Efficiency of Heavy Duty Trucks”. A Presentation to the European Commission. Brussels, November 2010.

region includes the large, industrial Midwest states such as Indiana and Illinois, and the heavily travelled Toronto-Windsor-Detroit-Chicago transportation corridor. PADD 1, with 28 percent of all registered heavy-duty vehicles (1,350,889 vehicles) encompasses the New England/Northeast area. This PADD is marked by dense population in several of its states, a large industrial base (in the case of states like New York and New Jersey), and several major ports, including the Port of New York/New Jersey and Norfolk, Virginia. PADD 3 (Gulf Coast) and PADD 5 (West Coast) have approximately the same number of vehicles registered (640,191 in PADD 3; 689,908 in PADD 5) and are home to some of the nation’s largest ports, biggest cities, and most frequently travelled transportation corridors. PADD 4, which includes the Rocky Mountain States of Colorado, Wyoming, and Utah, is a more sparsely populated region with no ports and less-travelled transportation corridors; only 5 percent of the nation’s trucks (227,526 vehicles) are registered in PADD 4 states.

**Figure 4: US Heavy-Duty Diesel Vehicles – 2011**
(by PADD)

Source: CERI, R.L. Polk & Co.

Figure 5 describes historical and potential growth in US heavy-duty diesel vehicles, according to the four future narratives: LNG Tsunami, Nowhere Fast, Power Wave, and Full Speed Ahead.
Two important assumptions were made for all four narratives in evaluating the US heavy-duty diesel vehicle category:

- **Mileage standards.** Recently announced US federal mileage and emissions standards for heavy-duty vehicles will begin taking effect in 2014 and will be fully implemented by 2019. The standards are applied to each narrative within the economic model. No new standards are assumed beyond 2019.

- **Average distance travelled per vehicle.** In the forty years from 1970 to 2010, average distance travelled per heavy-duty vehicle in the US increased an average 1.4 percent per annum. However, in the decade from 2000 to 2010, this rate slowed to 0.7 percent per annum. We assume in each narrative that the rate will continue to slow over the study period.

Figure 5 indicates that the most growth in heavy-duty diesel vehicles over the next decades will occur under the Full Speed Ahead narrative (see Appendix B for a breakdown by PADD of heavy-duty diesel vehicle growth). This narrative predicts robust GDP growth throughout North America in excess of 2.9 percent per annum over the entire period, so heavy-duty transportation would also grow to meet the demands of a prosperous, free-spending US economy. The new mileage standards would not meaningfully slow vehicle registrations under this narrative, nor would an oil price projected to be $130 per barrel in real 2010 dollars. By 2030, approximately 8,560,000 heavy-duty diesel vehicles would be registered in the US.

The LNG Tsunami narrative runs along similar lines to Full Speed Ahead. Though the new mileage standards slow vehicle growth slightly compared to Full Speed Ahead, the continuing strong economy (2.6 percent annual GDP growth over the period) pulls vehicle growth upward.
to 7,850,000 registered vehicles by 2030 – an increase of 63 percent over the 4,819,810 heavy-duty vehicles registered in the US in 2011. This growth occurs despite rising oil prices.

The rate of vehicle growth slows under the Power Wave narrative. This is mainly due to a sluggish economic recovery in the 2013-2017 period and the effects of the new mileage/emission standards to 2019. At its peak, GDP growth does not move beyond 2.2 percent annual growth under this narrative, so the demand for heavy-duty transportation is not as strong as under the two previously mentioned narratives. Nevertheless, Power Wave predicts 6,640,000 heavy-duty diesel vehicles to be on US roads by 2030.

Of the four narratives, only Nowhere Fast shows a period of decline in the number of heavy-duty diesels. The combination of deep economic recession and the new mileage/emission standards brings the total number of vehicles down to 4,600,000 by 2019. Under this scenario, GDP growth only begins to move above zero in 2018, and vehicle numbers do not recover to 2011 levels until 2024.

None of these narratives, even the economically pessimistic Nowhere Fast, indicates any kind of profound transformation in the way people and goods are moved in the US. The American economy is built around efficient transportation and inexpensive fuel to power vehicles. Nothing foreseeable indicates a significant change to that dynamic. Heavy-duty diesel vehicles, essential to the US economy since the US Interstate freeway system was built in the post-World War II era, will remain a preferred means of transportation for the conceivable future.

**US Fuel Usage**

Using historical vehicle registration numbers dating to 2005, and noting the new federal emissions/fuel usage regulations, historical vehicle numbers growth trends, average distance travelled per truck, and diesel fuel consumption patterns, we forecast fuel consumption trends across all four narratives over the study period. The heavy-duty diesel vehicle class is today the largest class in terms of fuel usage and it will remain so; though light- and medium-duty vehicles will grow in number under all four narratives, they do not travel anywhere near the same amount of distance per year per vehicle as heavy-duty diesels. For example, in 2011, the average heavy-duty diesel vehicle in the United States travelled 44,821 miles, whereas the average light-duty vehicle added 18,624 miles to the odometer and the average medium-duty vehicle travelled 18,711 miles. These mileage averages will change somewhat over the years, but the ratio of distances travelled by heavy- to medium- to light-duty vehicles will not vary significantly: heavy-duty vehicles are built for specific transportation purposes and will continue to move goods and people over longer distances than medium- and light-duty vehicles.

For all four narratives, we calculated historical fuel usage and future fuel usage under the new mileage/emissions standards. We then recalculated fuel usage without applying the new standards. The difference added up to the amount of fuel saved through fuel standards; it is captured in the area beneath the red dotted line (the “NO Efficiency Measures curve”, which denotes the amount of fuel that would be used if the new standards were not applied to heavy-duty diesels) and the top of the bars in each of the four following charts (Figures 6, 7, 8 and 9).
It should be noted that the fuel savings spread does not become noticeable in any of the charts until 2015, which is the second model year under which the new standards apply (see Appendix C for a breakdown by PADD of fuel usage).\textsuperscript{18} As the standards only apply to new vehicles, results are not immediately seen due to fleet turnover.

Fuel savings resulting from the new standards are largest under the Full Speed Ahead narrative. This is to be expected in the era of strong economic growth that this narrative represents. Heavy-duty vehicle operators will continue to purchase diesel fuel despite the new fuel standards; it is the cost of doing business in a booming economy. Likewise, under LNG Tsunami, fuel savings are large because the new standards are not felt as severely in the generally strong economy.

The standards are felt most in the Nowhere Fast narrative because they are yet another cost for heavy-duty diesel operators in a time when orders are slow coming in and the entire economy is performing poorly. The steepest decline in fuel usage under Nowhere Fast comes during the years in which the fuel/emissions standards are being applied (2014 to 2019). Only when the fuel standards are fully implemented does fuel usage slowly begin to rise again. This trend is also noticeable in the Power Wave narrative, though not to the same extent as in Nowhere Fast. Emissions calculations are beyond the scope of this study, though it should be pointed out that emissions would be lower under Power Wave and Nowhere Fast because of the lower fuel volumes being consumed.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure6.png}
\caption{US Diesel Usage by Vehicle Class – Full Speed Ahead}
\end{figure}

\textsuperscript{18} Fuel is saved in MY 2014 as well, but this is a small amount, not noticeable in the charts generated for this chapter.
Figure 7: US Diesel Usage by Vehicle Class – LNG Tsunami

Source: CERI, R.L. Polk & Co.

Figure 8: US Diesel Usage by Vehicle Class – Power Wave

Source: CERI, R.L. Polk & Co.
Canadian Heavy-Duty Diesel Vehicles

The nature of highway shipping changes from region to region in Canada: in the West, there are longer distances traveled and higher mountains crossed; Central Canada is the manufacturing heart of the nation – more densely populated with busier transportation corridors; the East, with its small population and less significant industrial base, relies the least on highway transport. Rather than consider the country simply as a whole, within this study we have also examined the three major regions: The West includes British Columbia, Alberta, Saskatchewan, and Manitoba. The East is comprised of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland. Ontario and Quebec form the Central Canada region. As shown in Figure 10, in 2011, Ontario and Quebec, with its large manufacturing base, busy border crossings into the United States, and large percentage of the Canadian population, held the most registered heavy-duty diesel vehicles (297,285 or 49 percent). The West, with major Pacific Rim ports in British Columbia and several large regional cities throughout the area, had 261,203 (43 percent) heavy-duty diesels under registration. In the four Eastern provinces there were 45,508 vehicles (8 percent) registered.
Figure 10: Canada Heavy-Duty Diesel Vehicles by Region – 2011

Source: CERI, R.L. Polk & Co.

Figure 11 describes historical and future potential growth in Canadian heavy-duty diesel vehicles, according to the four narratives considered in this study: LNG Tsunami, Nowhere Fast, Power Wave, and Full Speed Ahead.

Figure 11: Canada Heavy-Duty Diesel Vehicles – Total Vehicles on Road (26,000+ lb. GVW)

Source: CERI, R.L. Polk & Co.
Two important assumptions were made for all four narratives:

- **Mileage standards.** Canadian emissions/mileage standards will reflect US standards. The US federal government, after considerable deliberation and research, recently announced mileage and emissions standards for heavy-duty vehicles to begin in 2014 and be fully implemented by 2019. The Government of Canada, in February 2013, announced that new Canadian standards will align with the US standards. In this study, the new standards are applied to each narrative within the economic model. No new standards are assumed beyond 2019.

- **Average distance travelled per vehicle.** Canadian average distance travelled per vehicle will reflect US data. From 1970 to 2010, average distance travelled per heavy-duty vehicle in the US increased an average 1.4 percent per annum. From 2000 to 2010, this rate declined to 0.7 percent per annum. We assume in this study that the rate will continue to decline over the study period.

Historically, the vehicle growth curves between Canada and the US are similar: growth from 2005 to 2007, plateau from 2008 to 2010, and a drop in total vehicles from 2010 to 2011.

As would be expected because of the historically similar growth curves, the four narratives play out closely in Canada to the US over the coming years: Full Speed Ahead shows the greatest increase in numbers of heavy-duty diesel vehicles on Canadian roads over the next couple of decades, from 603,996 in 2011 to 1,060,000 in 2030; LNG Tsunami predicts slightly fewer vehicles (985,000); Power Wave indicates a total of 840,000 vehicles; and under Nowhere Fast, there will be approximately 40,000 more vehicles registered in Canada in 2030 than in 2011 (a total of 640,000). None of the four narratives points to a shift to alternative fuels. As is the case in the US, Canadian transportation infrastructure is crude-based and all indications are that there will be ample crude supply, and the means to refine it, for several decades to come.

**Canada Fuel Usage**

Each of the following four charts (Figures 12, 13, 14 and 15) represents one of the energy narratives and is listed according to amount of fuel consumed over the study period. As with the US Fuel Usage data, for Canada we use historical vehicle registration data, apply the new emissions/fuel usage regulations, historical vehicle number growth trends, average distance travelled per vehicle, and diesel fuel consumption patterns in developing our projections for total diesel fuel usage. Heavy-duty diesel fuel usage will remain greater than medium and light diesel fuel usage combined under all four narratives. Diesel highway transport will remain an important element of the Canadian economy, as it will in the United States.

For each narrative, we calculated historical and future fuel usage without applying the new fuel/emissions standards and then recalculated using the standards. We were able to then note the potential fuel savings with standards in place. Narratives in which more fuel is

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consumed show the greatest total savings. The economic effects of the new standards are seen most in Power Wave and Nowhere Fast, the two slow growth stories. Here the standards are palpable costs to operators because of the sluggish economic conditions, but once the standards are fully applied, by 2019, diesel fuel usage begins to grow once again.

Figure 12: Canadian Diesel Usage by Vehicle Class – Full Speed Ahead

![Figure 12: Canadian Diesel Usage by Vehicle Class – Full Speed Ahead](chart12.png)

Source: CERI, R.L. Polk & Co.

Figure 13: Canadian Diesel Usage by Vehicle Class – LNG Tsunami

![Figure 13: Canadian Diesel Usage by Vehicle Class – LNG Tsunami](chart13.png)

Source: CERI, R.L. Polk & Co
A Note on Natural Gas Vehicles

Natural gas as a transportation fuel has become a topic of debate in recent years. The North American natural gas supply glut, sustained low prices, and stiffening regulation on carbon-laden fuels have compelled a number of companies and governments to take a closer look at natural gas as an alternative fuel. Shell, for example, has announced that it will build an LNG refueling facility in Sarnia, Ontario to service LNG road vehicles, trains, and Great Lakes freight ships. Though there are no LNG-fuelled trains yet, research is well underway by BNSF and
others to develop new locomotives; despite the R&D and infrastructure costs involved, BNSF sees conversion of locomotives from diesel to natural gas as “transformational” and “right up there” with the transition from steam to diesel in the 20th century. Operators of Laker fleets also need to look at alternatives to the bunker fuels currently in use, not just to control fuel costs but to comply with new, stringent emissions standards on all vessels that operate within Canadian and US waters.

There is no question that natural gas holds some potential as a road vehicle fuel in North America. The technology has been proven for both CNG and LNG systems. In fact, in many parts of the world, these vehicles are in common use, especially in nations with a low capacity to refine oil. Countries such as Pakistan, Iran, and India have well-developed natural gas refueling infrastructure, and the cost of converting diesel and gasoline powered engines to CNG systems in those places is offset by the fuel cost savings that natural gas offers.

The situation is different in North America, which holds 23 percent of the world’s total refining capacity and a refueling infrastructure that is geared almost exclusively towards crude-based fuels. In the US, there is a nascent movement towards converting fleet vehicles such as buses and garbage trucks. In Canada, an important new project is the “Blue Road” being constructed along the transportation corridor between Quebec City and Toronto, with three LNG stations along that corridor to serve natural gas-powered long-haul trucks. Even more infrastructure is planned within both countries – spurred on by governments wishing to run cleaner and cheaper vehicle fleets and corporate citizens like T. Boone Pickens, who is the driving force behind the Clean Energy Fuels LNG stations in the US.

But despite these efforts and other endeavors in engine manufacturing and refueling technology, NGV’s are a very small component of a very large North American transportation market. Figure 16 shows the total number of heavy-duty diesels versus the total number of heavy-duty NGV’s in the US from 2005 to 2010. The gap is wide and has not narrowed noticeably, despite the efforts of Pickens and others.

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Barring a step change in engine manufacturing, transportation refueling infrastructure, and refining, NGV’s will likely remain a small percentage of the overall fleet. In terms of the four narratives, there is no significant penetration of NGV’s into the North American heavy-duty diesel market under Nowhere Fast. Penetration of 0.7 BCFPD by 2030 is forecast under LNG Tsunami, which would be about 2.1 percent of the diesel fuel usage total in that year, and the 1.8 Bcf/d penetration under Power Wave would be 6.4 percent of the diesel fuel total. At these numbers, NGV’s would likely not gather the critical mass required to begin displacing heavy-duty diesels. These numbers are more or less in line with other projections by other organizations, such as the International Energy Agency (IEA). For example, in the 2013 Annual Energy Outlook, the IEA Reference Case scenario projects natural gas for transportation consumption to be 3.2% of diesel consumption by 2030.²⁶

Consider, however, the narrative that presumes the most movement of natural gas into the transportation sector – the 2.4 Bcf/d by 2030 forecast under Full Speed Ahead would equate to 6.7 percent of the diesel fuel total and approximately 10 percent of the diesel fuel used in the heavy-duty vehicle category. Figure 17 indicates the amount of diesel fuel that could be

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²⁵ US statistics for NGV’s may be found at the Renewable and Alternative Fuels section of the EIA website: [http://www.eia.gov/renewable/afv/users.cfm](http://www.eia.gov/renewable/afv/users.cfm)

displaced by natural gas within the heavy-duty vehicle category, with the orange portion of the graph representing natural gas usage. This graph does not indicate a revolution in transportation fuel usage, but it points to a potentially significant contribution by natural gas in the years after 2030.

**Figure 17: Full Speed Ahead: US Heavy-Duty Fuel Usage – NGV’s and Diesels (2012-2030)**

Figure 18 shows how vehicle numbers would increase over the next two decades, with diesels totaling 7.7 million vehicles by 2030 and NGV’s approaching 1 million vehicles (864,000). Heavy-duty NGV’s would then represent 10 percent of all heavy-duty vehicles on US roads, a significant number, though still far short of a dominant position in the fleet. As the numbers of heavy-duty natural gas vehicles grow, so will fuel usage; but this is a situation most likely to occur well into the future, beyond the timeline considered in this study.

Source: CERI, R.L. Polk & Co.
Figure 18: Full Speed Ahead: Heavy-Duty Vehicle Totals – NGV’s and Diesels (2012-2030)

Source: CERI, R.L. Polk & Co.
Appendix A

CERI’s Four Narratives, a Synopsis

CERI’s research into the future of North American natural gas supply and demand to 2030 is based on multiple scenario modeling of the North American natural gas market. The models are robust and broad in scope, each encompassing a number of macroeconomic assumptions, including: GDP growth rate, industrial production growth rate, oil price, inflation rate, and population growth. They also include assumptions about weather, non-power gas demand, power gas demand, coal plant growth/retirements, and nuclear power plant growth/retirements. Below is an overview of each scenario:

1. **Nowhere Fast.** This is the most pessimistic narrative in terms of economic growth. A series of economic blows cause a global recession. China-US geopolitical tension affects trade as low oil prices and protectionism stifle LNG exports from North America to points abroad. Falling oil prices, excess supply, and the loss of both local and traditional natural gas markets hit already challenged producers. Gas prices plummet and margins are lost.

2. **Power Wave.** Intense global competition, regulatory delays, and other uncertainties suppress North American LNG exports. However, practical domestic policy and a vigorous market support natural gas penetration into power and industrial markets. Though economic growth is slow in the early years, it picks up and demand for natural gas gains solid momentum.

3. **LNG Tsunami.** Global LNG demand grows, driving natural gas prices higher and resulting in aggressive development of LNG liquefaction and export infrastructure throughout North America. Both coal and renewables gain approval among the public, which leads to favourable policy for these two energy sources; however, domestic North American natural gas demand falls as a result. Regulation causes higher fracking costs and restricts both shale gas and tight oil development.

4. **Full Speed Ahead.** This is the most optimistic narrative in terms of economic growth. A strong global economy and sustained high oil prices lead to increased demand from Asia for LNG. Carbon-constraints bolster development of gas-powered generation and also cause LNG demand to grow. The transportation sector sees more NGV’s on the road because of society’s desire to limit carbon emissions.
Appendix B
US Heavy-Duty Diesel Vehicles by PADD – Four Narratives

Figure B.1: US Heavy-Duty Diesel Vehicles – Total Vehicles on Road, PADD 1
(26,000+lb GVW)

Source: CERI, R.L. Polk & Co.

Figure B.2: US Heavy-Duty Diesel Vehicles – Total Vehicles on Road, PADD 2
(26,000+lb GVW)

Source: CERI, R.L. Polk & Co.
Figure B.3: US Heavy-Duty Diesel Vehicles – Total Vehicles on Road, PADD 3
(26,000+lb GVW)

Source: CERI, R.L. Polk & Co.

Figure B.4: US Heavy-Duty Diesel Vehicles – Total Vehicles on Road, PADD 4
(26,000+lb GVW)

Source: CERI, R.L. Polk & Co.
Figure B.5: US Heavy-Duty Diesel Vehicles – Total Vehicles on Road, PADD 5 (26,000+lb GVW)

Source: CERI, R.L. Polk & Co.
Appendix C
US Heavy-Duty Diesel Fuel Usage by PADD – Four Narratives

Figure C.1: US Heavy-Duty Diesel Vehicles – Fuel Usage, PADD 1
(26,000+lb GVW)

Source: CERI, R.L. Polk & Co.

Figure C.2: US Heavy-Duty Diesel Vehicles – Fuel Usage, PADD 2
(26,000+lb GVW)

Source: CERI, R.L. Polk & Co.
Figure C.3: US Heavy-Duty Diesel Vehicles – Fuel Usage, PADD 3
(26,000+lb GVW)

![Figure C.3: US Heavy-Duty Diesel Vehicles – Fuel Usage, PADD 3](image)

Source: CERI, R.L. Polk & Co.

Figure C.4: US Heavy-Duty Diesel Vehicles – Fuel Usage, PADD 4
(26,000+lb GVW)

![Figure C.4: US Heavy-Duty Diesel Vehicles – Fuel Usage, PADD 4](image)

Source: CERI, R.L. Polk & Co.
Figure C.5: US Heavy-Duty Diesel Vehicles – Fuel Usage, PADD 5
(26,000+lb GVW)

Source: CERI, R.L. Polk & Co.