Report of a study conducted by the
North American Council for Freight Efficiency

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Contents

1 Executive Summary 5
2 Introduction 8
2.1 Overview 8
2.2 Background 9
3 Price of Fuel 12
4 Technology Adoption by the Fleets 13
4.1 Fleet Adoption Diversity 13
4.2 Technology Adoption Curves 14
4.3 Fleet Consistency of Adoption 15
5 Efficiency and Purchase Content of Latest Equipment 17
6 Fuel Savings from Efficiency Actions 17
7 Trucking Efficiency Confidence Reports 20
8 Value of Technology Adoption 21
9 Study Highlights 22
9.1 Dissimilar Fleet Adoption 23
9.2 Technology Adoption and the Final Greenhouse Gas Rule 25
9.3 Productivity and Miles Driven Annually per Truck 29
10 Conclusion 31
11 References 32
12 Appendices 33
12.1 Appendix A: Adoption of Technologies by Fleets 34
12.2 Appendix B: Adoption Scaled by the Number of Miles Driven 35
12.3 Appendix C: Adoption Curves by Category 36

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1 Executive Summary

This report contains the results of a deep-dive investigation into the adoption of various products and practices for improving freight efficiency among 17 major North American fleets. This is the fourth annual update of the 2011 inaugural study that has been called "The most comprehensive study of Class 8 fuel efficiency adoption ever conducted" (Truck News, 2012). The findings of this report should prove invaluable to efforts both to improve the fuel economy of a fleet and to develop and deliver fuel efficiency products to the marketplace.

The scope of this work encompassed Class 8 tractors (daycabs & sleepers) and trailers in regional and long haul applications. Fleets providing data for this 2016 study include Bison Transport, Cardinal Logistics, CR England, Challenger Motor Freight, Crete, Frito Lay, Maverick, NFI Industries, Nussbaum, Paper Transport, Prime, Ryder System Inc., Schneider, United Parcel Service and XPO Logistics. Two more fleets have supplied data in the past, but were not able to do so in 2016. The primary goal was to study their levels of adoption of 69 technologies and practices, and the results those drove in each organization. All 69 are currently available technologies, and not prototypes, validation test units, or pre-production units. This study focuses on what was actually purchased and implemented onto a fleet's trucks and trailers. In certain cases, fleets were asked if they had retrofitted any of the devices on their equipment, but this was done for context, and is not included in the adoption data.

The primary finding of this report is that the 17 fleets studied are increasing their rate of adoption of these technologies, and that they are enjoying improved fuel economy as a result. The overall adoption rate for the technologies studied in this report has grown from 18% in 2003 to 43% last year. Not all technologies could be applied to a single tractor trailer, as some are clearly and either or decision. 2015 was the first full calendar year of the lower fuel cost at the pump and the study team was interested to understand if the lower fuel prices caused these fleets to buy less of these technologies, which overall they have not. Diesel fuel, which powers a large majority of this fleet, averaged $2.71 per gallon for 2015 (EIA, 2016), down from the previous four years' average of $3.89. See Figure 1.

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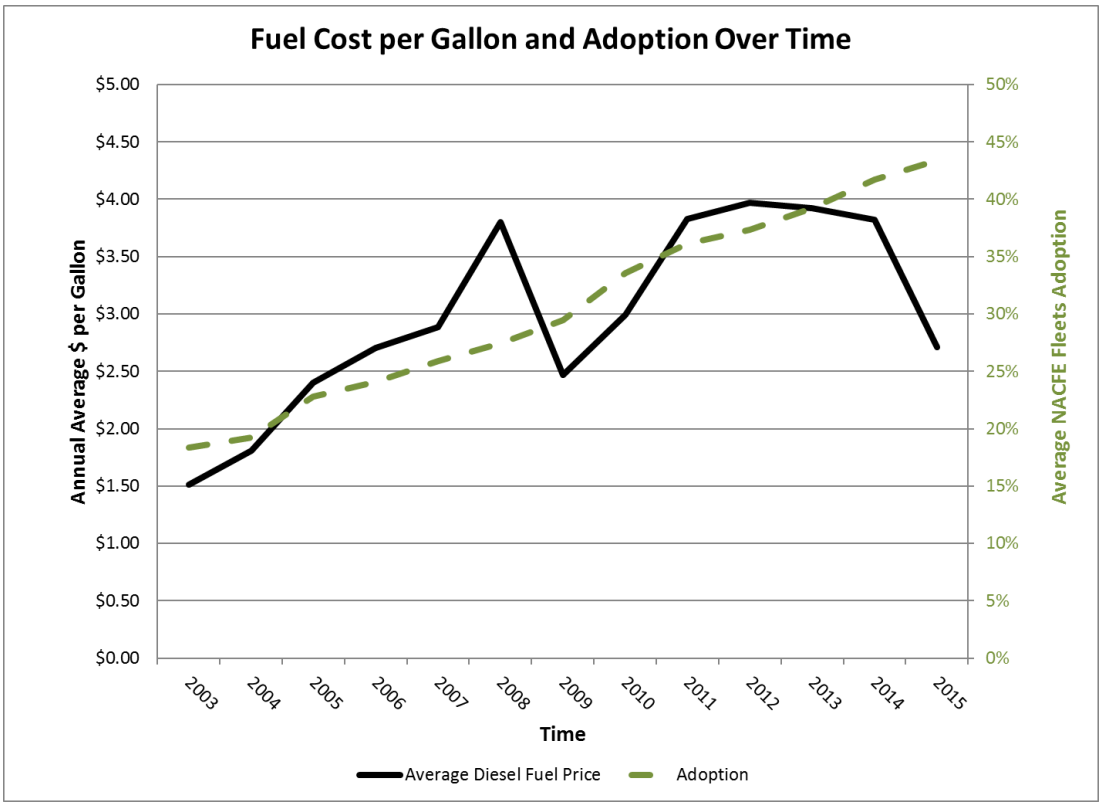

Figure 1: Price of Diesel and NACFE Fleets Adoption

The average fleet-wide fuel economy of the trucks in this study averaged 7.06 MPG in 2015, a 3% increase over the same fleet in 2014. The fleets in this study on average sell their trucks in 5.25 years, which is sometimes called turnover. This suggests that the new trucks put into service in 2015 (2016 Model Year) by these fleets were about 16% better than the ones removed — the ones which had been put into service in 2009 (2010 MY). This is a significant improvement in fuel efficiency and after discussing this with various companies in the industry, it was determined to be caused by three basic elements; movement to EPA2010 systems using Diesel Exhaust Fluid, the 2014 GHG phase 1 products and the year-over-year increase in adoption of the technologies included in this study.

Figure 2 shows the average fleet-wide fuel economy for the combined population of trucks in this study compared to the overall US truck population. A business-as-usual (BAU) line is included for comparison, showing a projection of what average MPG might have been given the combined impact of 2002, 2007 and 2010 emission regulations, and an assumption for the effect of 2014 GHG base powertrain improvements. The national average for all, approximately 1.7m tractors in over the road use, is shown and was obtained using International Fuel Tax Reporting data from the Federal Highway Administration (FHWA, 2016).

The fuel savings in 2016 between the business-as-usual 6.30 MPG and the NACFE fleets average of 7.06 MPG amounts to $4,653 per year per truck, at the $2.71 per gallon fuel cost over the average tractor mileage of 99,958. The fleets are saving $8,075 over the national average of 5.83 MPG. If fuel costs had been at the 4-year average of $3.89 per gallon the savings would have been $6,679 and $11,591, respectively. And finally, for these 17 fleets operating 62,123 trucks, in 2015 combined they saved $500,635,787 compared to the average trucks on the road.

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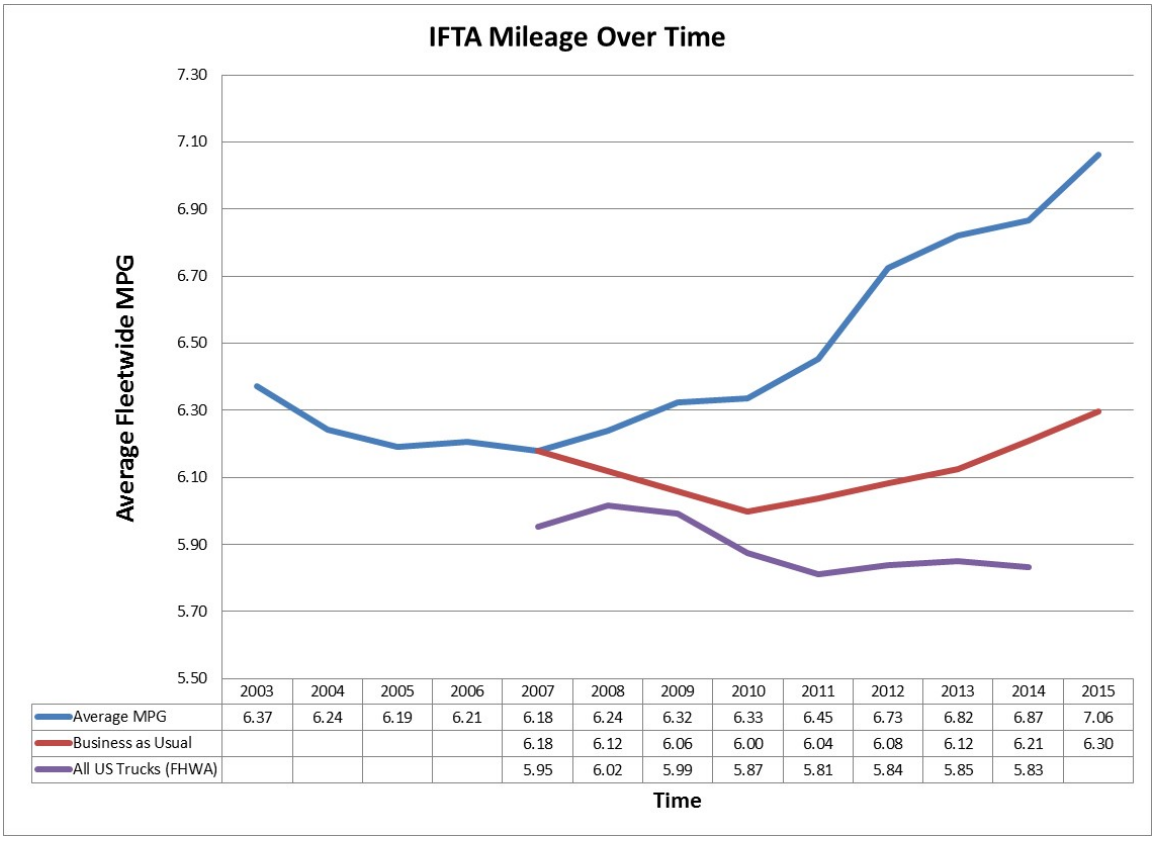

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Average MPG	6.37	6.24	6.19	6.21	6.18	6.24	6.32	6.33	6.45	6.73	6.82	6.87	7.06
Business as Usual					6.18	6.12	6.06	6.00	6.04	6.08	6.12	6.21	6.30
All US Trucks (FHWA)					5.95	6.02	5.99	5.87	5.81	5.84	5.85	5.83	

Figure 2: Average Fleet-wide Fuel Economy over Time

With so much data available there are many items of note, but three more stood out to the study team for sharing. First, even these 17 fleets varied in the choices they make in fuel efficiency solutions, starkly shown in their adoption of Idle Reduction solutions. Some fleets are using diesel APUs, others electric HVAC systems, others automatic start stop and some managing idle with engine parameter settings, diesel fired heaters and driver training and incentives. Second, the final EPA and NHTSA Greenhouse Gas and Fuel Efficiency Regulations estimate a longer term adoption of various technologies that are able to be compared to the adoption of the same technologies by these fleets. This demonstrates the improvement needed in the total cost of ownership or payback required for these technologies to be valued and purchased by fleets. And finally, the study team will share some interesting facts about truck productivity even in the face of lower miles driven per truck.

It is our goal that the information shared in this study provide other end user fleets a roadmap in navigating the many available technologies that can have a positive impact on lowering fuel expenses. A benchmarking tool is being released with this study that can be used by any truck owner to compare their own technology adoption to these fleets. We expect it will be helpful in your efforts.

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2 Introduction

2.1 Overview

The North American Council for Freight Efficiency (NACFE, www.nacfe.org) is a nonprofit organization dedicated to doubling the freight efficiency of North American goods movement. NACFE was created in 2010 to bring solutions to the freight industry which radically increase fuel efficiency, by serving as an independent, unbiased research organization for the transformation of the transportation industry. Success for NACFE includes providing a place for the significant sharing of proven products and practices and identifying those that are not promoting the efficient movement of goods. This study highlights the success achieved by some of the more innovative fleets in North America; we hope that by giving them an opportunity to share this information we will encourage quicker adoption rates.

Late in 2013, NACFE entered into a cooperation with the Carbon War Room (CWR, www.carbonwarroom.com), a nonprofit founded by Sir Richard Branson and dedicated to scaling energy efficiency technologies. Recognizing the opportunity to accelerate the trucking sector's fuel efficiency, NACFE and CWR launched the Trucking Efficiency operation. Trucking Efficiency collaborates with industry experts to address the barriers to the large-scale deployment of freight-efficiency technologies for tractors and trailers. The group completes Technology Overviews and Confidence Reports on promising available technologies, holds workshops to openly debate their findings and recommendations, and launched an online Tech Guide in late 2014, www.truckingefficiency.org, which collects all of this information into one centralized location. By mid-2016, the group has published 13 confidence reports covering more than 50 of the technologies available to Class 8 over-the-road fleets. Success for Trucking Efficiency will be measured in the accelerated adoption of technologies and practices that promote freight efficiency (Figure 3).

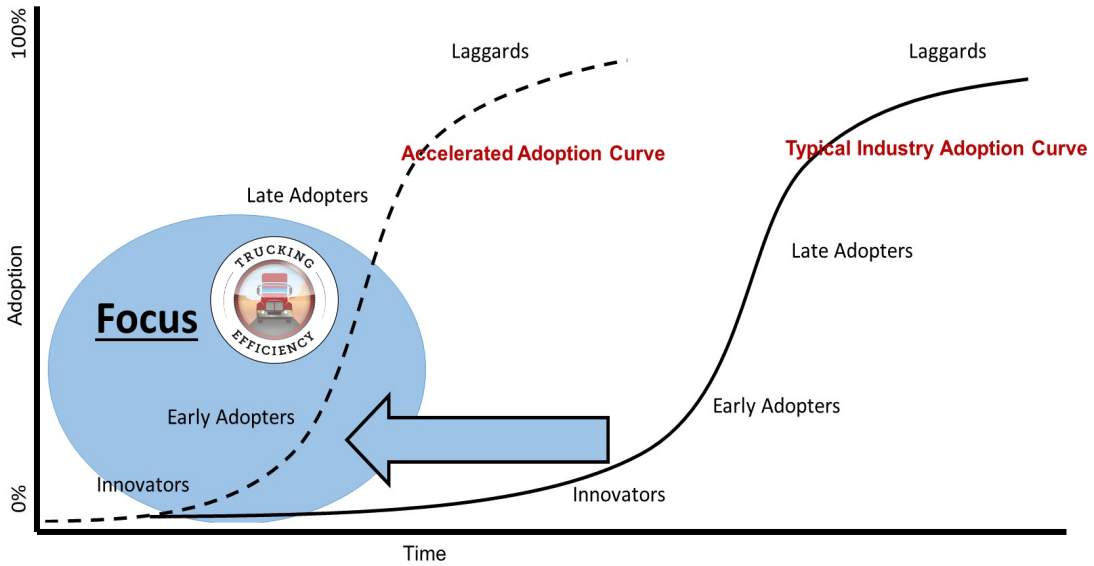

Figure 3: Accelerating Adoption at NACFE

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2.2 Background

The fuel costs faced by the tractor-trailer industry have been swiftly and steadily rising over the past decade and had averaged $3.89 for the last four years up to the end of 2014 (EIA, 2016).

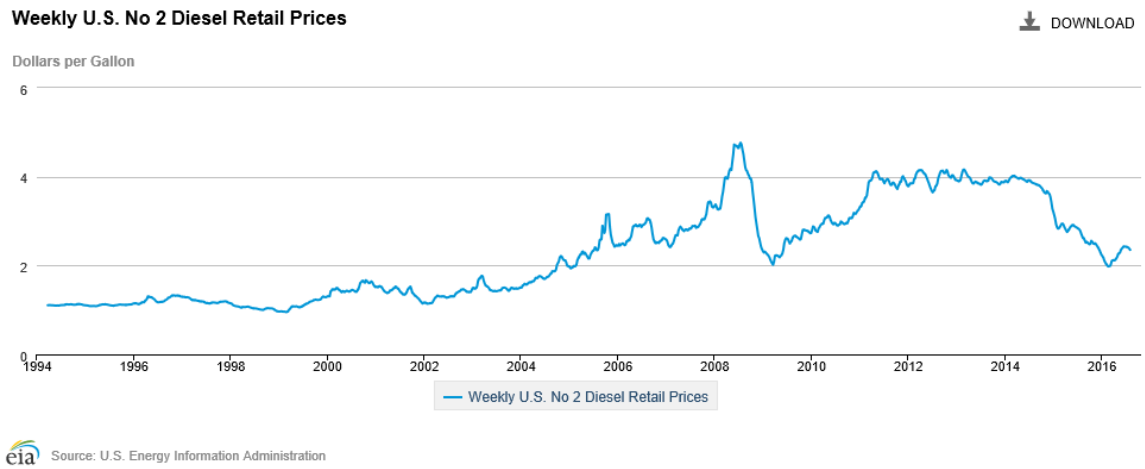

Figure 5: U.S. Annual Diesel Fuel Prices

As shown in Figure 6, by 2013, fuel costs had reached $0.65 per mile, as reported by the American Transportation Research Institute, surpassing even the costs for the driver (wages plus benefits) (ATRI, 2015). These costs have driven fleets to want to include fuel efficiency in their new equipment specifications and operational strategies, but many do not know where to start. Very recently prices have dropped and this report reflects purchase decisions for technologies and their results for the time period up to the end of 2015, which was the first full year of lower fuel prices. More on lower fuel prices later.

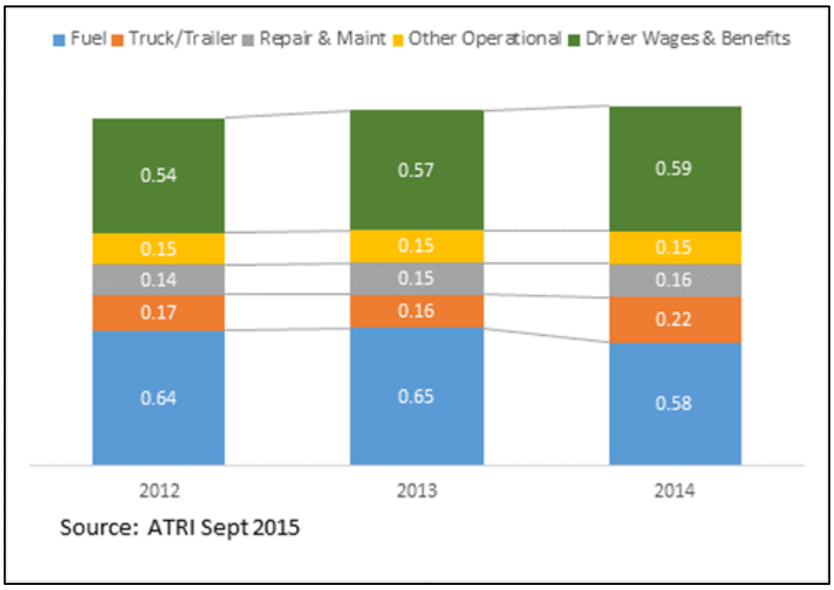

Figure 6: HD Tractor Operating Costs per Mile

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Investment in proven technologies and practices that allow a truck or fleet to increase its fuel efficiency – meaning that they let the fleet do the same amount of business while spending less on fuel – is a hugely promising option for the industry in light of these trends.

However, the vast diversity of needs in the industry can make adoption difficult. These needs are driven by multiple and sometimes seemingly incompatible demands, including a fleet's access to capital, level of risk tolerance, and even their business model (lease vs buy equipment, use company drivers or independent contractors, in-house or contracted maintenance). Moreover, the equipment must operate in differing duty cycles, created by variations in operating locations (urban, rural, or a combination) and/or geographies (mountainous/flat, hot/cold, etc.). These factors combine to create a significant challenge for end users seeking to determine which technologies to pursue and which companies to consider purchasing from.

To better understand the history of adoption, in 2010 NACFE created a methodology for sharing best practices, in order to document and learn from data-driven fleets, and provide an early roadmap for the industry on technologies that improve the efficiency of Class 8 tractor trailers. By this report, the fifth annual fleet fuel study, completed in 2016, data has been accumulated on the purchasing habits of 17 fleets, operating more than 62,000 tractors and nearly 217,000 trailers. To be included in this dataset, fleets provided data on the tractors and trailers for which they specified the features (technologies) and purchased the fuel for the tractors. This makes for a clean dataset for comparing the fuel efficiency to the adoption decisions. For instance, Ryder owns about 65,000 Class 8 tractors, but only buys fuel for 3,100 of them in their dedicated operations. Only those tractors are included in this study.

Information gathered and shared in this report includes the percent of each fleet's annual purchases that involved any of 69 currently available technologies for lowering fuel consumption, from 2003 up to 2015. They also shared their overall fleet-wide fuel efficiency in terms of miles travelled and fuel consumed. A summary of the technologies is shown in Figure 7. With 69 technologies, 17 fleets and 13 years of data, this process provides about 15,000 data points of purchasing behavior on new features by these end users. It should be noted that three new fleets are joining the study this year and given their new data, which extends back to 2003, this year's report is not directly comparable to last year's report. All years' adoption decisions and fuel economy have changed.

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Figure 7: Technologies to Save Fuel

This report distills those data points into adoption curves for all technologies, fleet diversity of adoption, and the associated fleet-wide fuel economy average, for all 13 years in the study period. See a representation of all 69 technology adoption curves in the figure below.

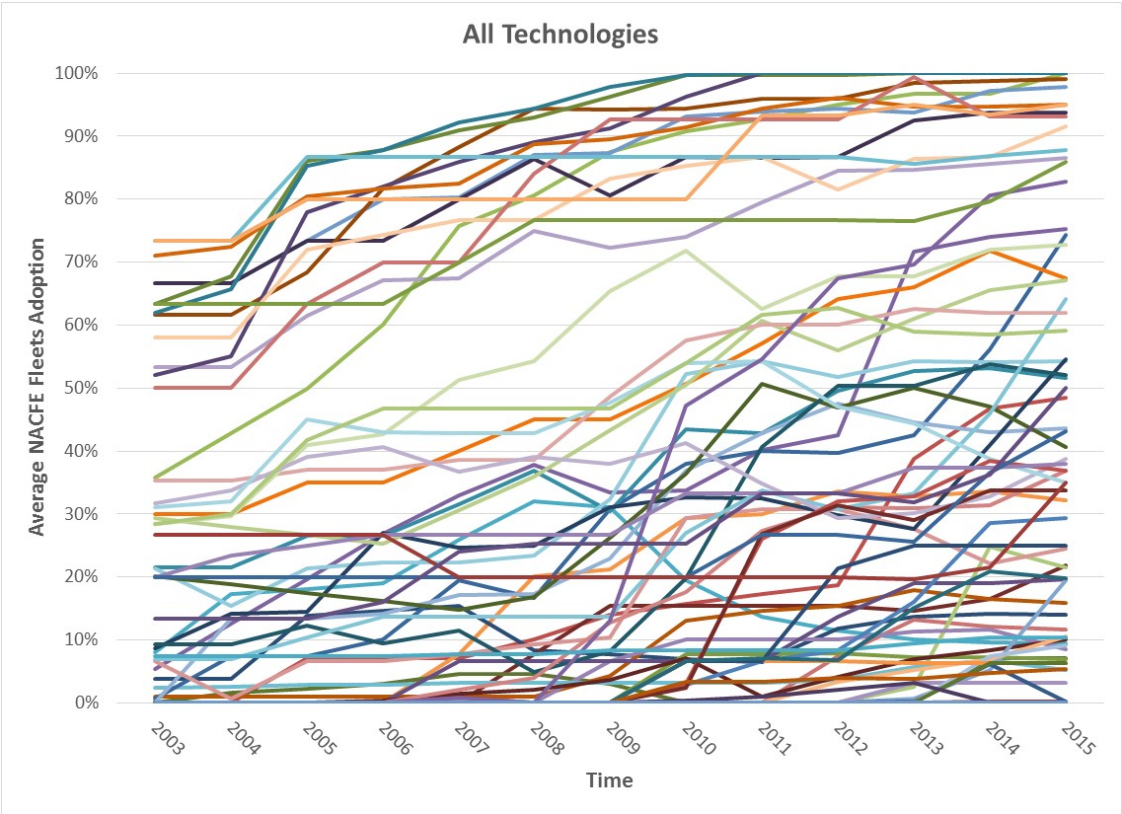

Figure 8: 69 Adoption Curves

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The percent adoption of a technology is a measure of the rate at which fleets purchased a given technology or implemented a given practice in any particular year. The primary goal is to determine adoption in terms of each fleet's selection and use. Therefore, the adoption percentage is not weighted by the number of tractors or trailers purchased per year by the fleet. It measures fleet decisions, rather than the number of trucks with the technologies. Under this methodology, a decision made by the smaller fleets, that purchase about 100 trucks per year, has the same value as that of the largest fleet buying thousands. The calculations for the data provided in Appendix B, are as follows:

- Each Technology Adoption
  - % Adoption = (% of new trucks purchased with technology @ fleet A + % @ fleet B + …) / Number of Fleets
- Technology Adoption across all Fleets
  - Total % Adoption = (% Tech Adoption #1 + % #2 + …) / Number of Technologies

This year additional data (Appendix B) is provided as a truer representation of the absolute number of new technology products are sold in each year. Here the data from Appendix A is recalculated using the miles travelled by each fleet. This methodology therefore does value a purchase of 2,000 per year of a given technology by a large fleet as 20 times greater than someone buying only 100 new trucks.

Armed with this powerful data, much can be learned about the past and inferred to help forecast the future of these features. The opportunity is enormous as there are about 1.7 million tractors operating in the U.S. consuming approximately 26B gallons of diesel fuel. For every 1% reduction in fuel use, 260M gallons of fuel or about $1B per year are saved.

3 Price of Fuel

We would be remiss if we did not address the subject of the recent drop in fuel prices in this report.

While it's true that diesel fuel prices are at their lowest levels in five years, if history is any indication, they won't stay low forever. The U.S. Energy Information Administration's Short-term Energy Outlook shows that, while the on-highway retail price of diesel will actually decline further in 2016 to $2.36, by 2017 it will be back up to $2.71 a gallon. Longer-term predictions are for prices to rise to more than $6 a gallon by 2040 (EIA Outlook, 2016).

It is important to remember that the U.S. is not the only country that consumes crude oil. Developments in other parts of the world, including growing economies, will impact the price of crude and by extension the price of diesel. Diesel prices, like all other products, are subject to the laws of supply and demand. When demand goes up, prices usually increase as well.

The cost of fuel must be taken into account when doing payback calculations for investments in fuel efficiency technologies. But regardless of the price of diesel, fleets would be unwise to lose their focus on improving fuel economy. Yes, lower diesel prices make the paybacks for some technologies longer, but the price of diesel isn't the only reason fleets should strive to improve their fuel economy. Whether fuel is $4 a gallon or $2 a gallon, when you improve fuel economy you cut expenses from the bottom line.

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"Continuing to make investments in technologies that improve fuel efficiency makes good sense despite the current low price of diesel fuel," says a senior executive at one of the large carriers. He continues, "Given the historic volatility of oil prices, it's a safe bet that we'll see the price of diesel go up before long. Fleets who've improved their fuel economy will be at a competitive advantage when that happens."

Another consequence of returning to past equipment specifications was shared by numerous fleets, that is summarized as change management. It is very difficult for fleets to move to these new technologies; drivers need to be educated on how to drive them, technicians on how to fix them, sometimes it requires new suppliers, and many other execution actions. To return to an old feature and then maybe back to the fuel saving technology, when fuel prices rise, can take years and a lot of money. These fleets generally stated that they try to make the new specifications the new norm and don't look back, unless the costs to operate are higher than predicted or the new technology causes significant downtime. For these fleets, lower fuel costs in the possible short term is not reason enough to revert to old specifications.

4 Technology Adoption by the Fleets

This section will describe the technology adoption with respect to their fleet diversity, individual technology curves and the consistency of technology adoption across the fleets. For the first time, this data is provided in a separate spreadsheet that allows the reader to analyze the information further. Please contact NACFE with specific questions if further clarification is needed.

4.1 Fleet Adoption Diversity

As is true for nearly all products, be they business-to-consumer or business-to-business, trucking end users tend to fall into different categories when new offerings become available. Some adopt early while some wait to learn from others' experience – depending on their own calculations of the benefits versus the risks of being on the leading edge of new technologies. The 17 fleets (identified as fleets A to Q due to privacy agreements) in this study are no different (Figure 9). Four fleets have adoption, of more than 50%, as defined in this report, while 8 are between 40 and 50% and five are between 30 and 40%. The first four are the most aggressive adopters in 2015, but a closer look shows that two of them were not always leading. Two fleets, A and K, moved from under 20% in 2003 to more than 50% in 2015, showing a remarkable increase in use of these freight efficiency technologies. They became very committed to specifying these technologies on their new equipment. A large number of fleets have consistently increased their adoption in a methodical manner. But Fleet N which had the highest level of adoption in 2003 and 2004, is now in the middle at number 9.

It is important to note that no fleet could adopt all 69 technologies on a single tractor-trailer combination, as some are "competing" solutions for a single function. For instance, a truck would not have both a diesel auxiliary power unit and a battery heating, ventilating and air conditioning (HVAC) system. The maximum adoption by a fleet would be around 65%, depending on the set of technology combinations. The fleets in this year's study range from about 30% to 56% of the available technologies employed on their tractors and trailers.

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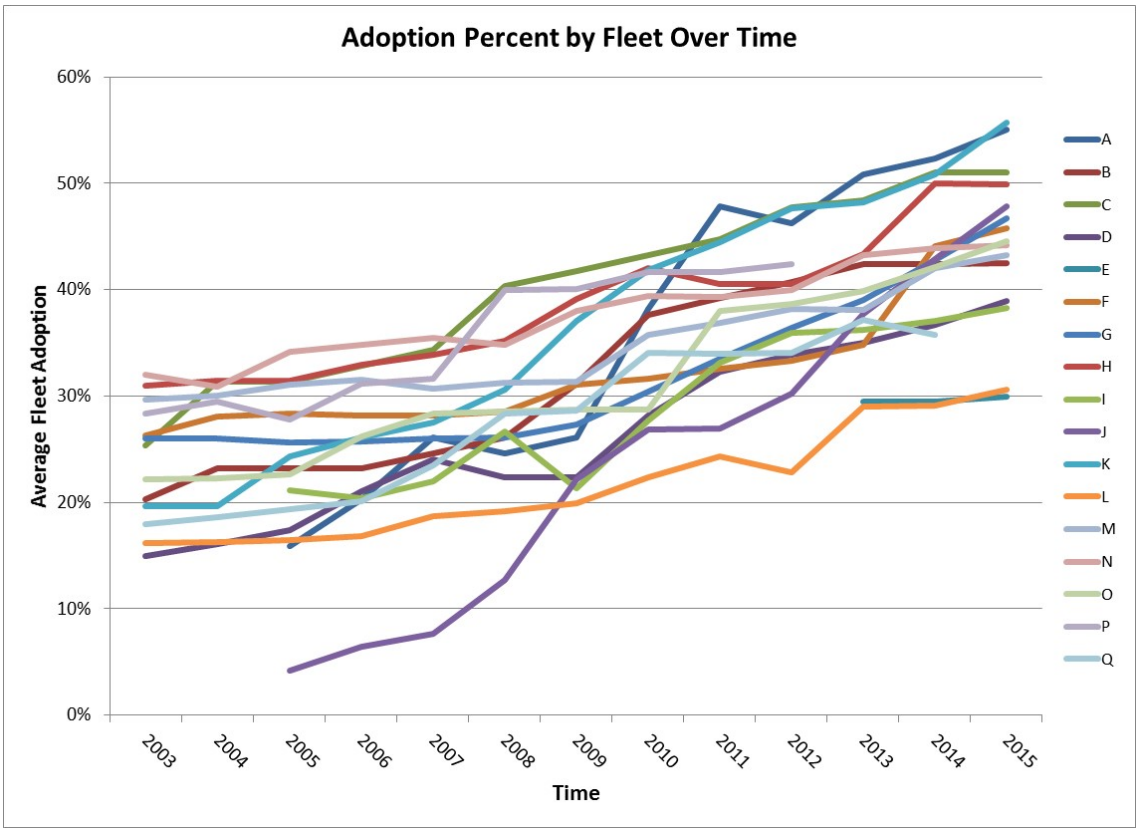

Figure 9: Fleet Adoption over Time

4.2 Technology Adoption Curves

Given the data provided, 69 adoption curves were created and are shown in the appendices. Keep in mind that these charts show only the adoption practices of the 17 fleets studied, which represent about 4% of the overall heavy-duty over-the-road vehicles in North America. They also show each fleet as a single decision in the adoption calculation; fleets are not weighted by the total volume of tractors or trailers procured or miles driven. This provides new insight into not only the current level of adoption, but into the ramp up over the last decade. For example, the ramp up of the purchase of trailer skirts to over 83% adoption is the quickest current rate of all technologies.

The 69 technologies were grouped into seven categories: tractor aerodynamics, trailer aerodynamics, powertrains, tires/wheels, idle reduction, chassis, and fleet practices. Technology adoption by category is displayed here in Figure 10, while the adoption curves for each technology are provided in the appendix. All categories show increasing levels of adoption with trailer aerodynamics increasing the most dramatically in the last five years.

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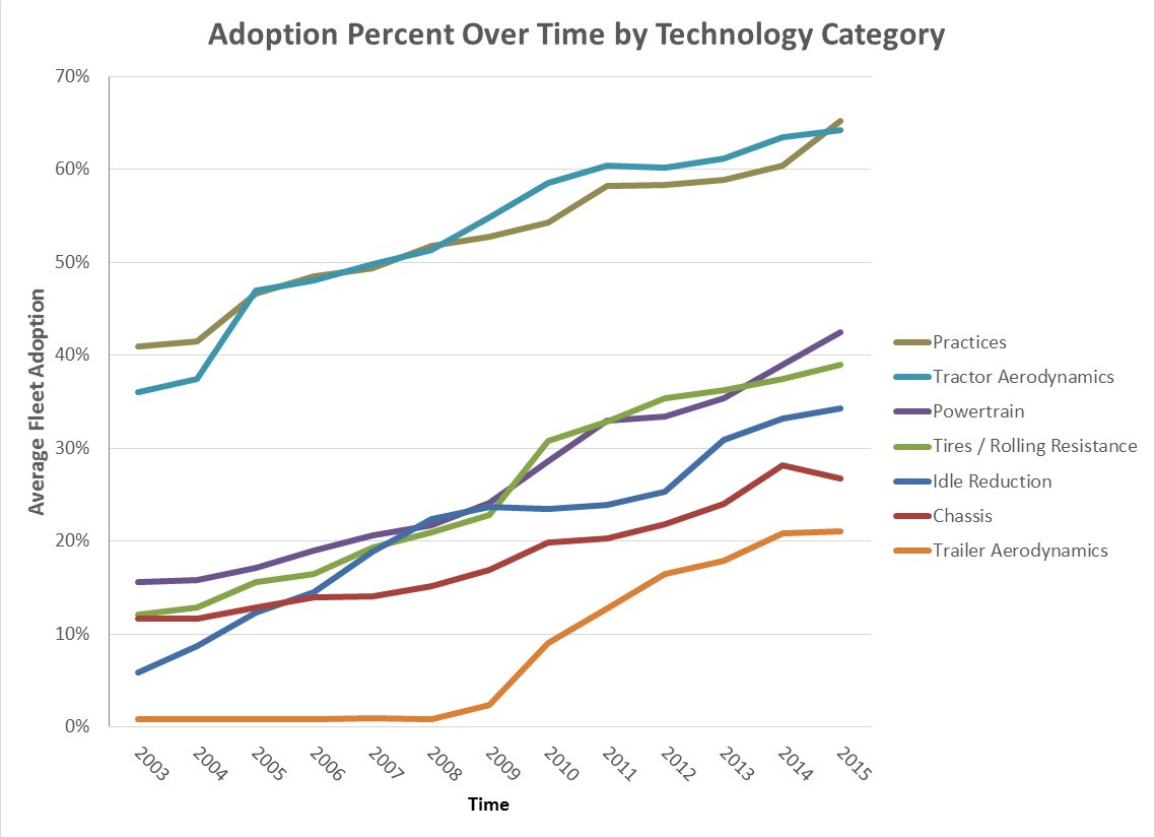

Figure 10: Adoption by Category

4.3 Fleet Consistency of Adoption

Finally, as in previous years' reports, the consistency of adoption by the various fleets was evaluated. To do so, each of the 69 technology decisions (i.e. whether to adopt or not) made by each of the 17 fleets is compared using a categorization methodology showing whether the technology is being purchased by the fleet, how quickly the fleet moved from testing the technology on a few vehicles to specifying it on 100% of all purchases, or even if a fleet decided to stop buying something after initial deployment. Figure 11 includes this data demonstrating the technologies' adoption stacked in order of popularity, by the various fleets denoted by A to O.

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Anti Idle Electronic Engine Controls	5	5	5	4	5	5	5	5	4	5	5	5	5	4	5
Aero hoods and fenders	5	5	5	4	5	4	4	5	5	4	5	5	5	5	5
Aerodynamic bumpers	5	5	5	4	5	4	4	5	5	5	4	5	5	5	4
Aerodynamic mirrors	5	5	5	4	5	4	4	5	5	4	5	5	5	5	4
Engine parameters set for fuel economy	5	5	5	5	3	5	4	5	5	3	5	4	5	5	5
Synthetic axle lube	5	5	5	5	5	5	3	5	5	3	5	5	5	5	5
Full height roof air fairing	5	5	5	4	3	5	3	5	5	5	5	3	3	5	5
Driver training for fuel economy	5	5	5	5	3	5	5	5	5	5	5	5	5	5	5
Synthetic transmission oil	1	5	5	5	5	5	5	5	5	5	5	5	5	1	5
Limit Speed <65 mph	5	5	5	5	5	5	5	5	5	5	5	5	3	5	5
Cab extenders	5	5	1	4	5	5	3	5	5	5	4	3	3	5	5
Reduce empty miles	5	5	5	1	3	5	5	5	5	3	5	5	5	5	5
Aluminum wheels tractors	5	5	5	5	3	5	3	5	4	5	4	3	5	5	1
Routing optimization	1	5	5	1	3	5	5	5	5	5	5	5	5	5	5
Trailer skirts	5	5	5	1	3	4	3	5	5	5	5	3	3	5	3
Diesel Fired Heater	5	5	5	3	3	4	3	5	5	3	2	3	3	5	1
Tire pressure inflation - trailer	5	5	5	3	3	5	3	4	5	3	5	3	3	4	5
Tractor chassis skirts - full	5	5	5	1	3	4	4	3	5	5	2	3	3	5	1
LRR duals - trailers	1	5	3	1	5	5	5	5	5	3	5	3	3	5	5
Downspeeding (Rear ratio<2.7:1)	5	5	1	4	3	3	3	1	6	3	5	3	3	5	5
Lower viscosity engine oil xW-30	5	5	5	1	1	1	3	5	1	5	4	5	5	5	5
Remove parts - bug deflectors, etc.	5	1	5	1	5	5	4	3	1	5	4	1	5	5	1
Specified weight reduction on tractors	5	5	5	1	5	1	5	5	1	3	5	5	5	5	1
Automated manual transmissions	5	3	5	3	3	5	3	3	3	4	3	3	3	4	5
Aluminum wheels trailers	5	5	5	3	1	5	3	4	1	4	4	3	1	5	1
Downsize engine (e.g. 15L - 13L)	1	3	5	5	3	1	3	3	5	3	5	3	3	3	5
LRR duals - tractors	1	5	1	1	3	5	3	5	5	3	5	3	3	1	5
Coasting before engine braking	5	3	5	4	3	1	3	5	1	5	1	1	5	5	1
Highest level of cab insulation	1	3	5	4	5	1	1	5	5	5	5	1	3	1	1
Wide based tires - tractors	5	5	5	4	3	2	3	1	1	1	1	3	3	5	1
Driver incentives for FE	5	5	5	1	3	1	3	1	1	5	1	1	5	5	1
Direct drive transmission	5	2	5	4	1	1	3	3	5	1	2	3	3	2	2
Tractor chassis skirts - partial	1	2	1	3	3	4	4	3	1	3	5	3	1	1	3
Specified weight reduction on trailers	1	5	5	1	5	1	1	5	1	1	5	1	3	5	1
Predictive cruise control	5	3	1	3	3	5	3	4	1	3	1	3	3	1	5
Vented mudflaps - tractors	5	1	1	4	3	1	3	3	1	5	5	1	1	1	5
In cab Cameras	5	3	5	3	1	1	5	3	1	2	1	3	1	5	1
Fixed 5th wheel w/ minimum gap	2	1	1	5	1	2	3	5	5	2	1	3	3	5	5
Vented mudflaps - trailer	5	1	1	3	1	1	3	3	1	5	5	1	1	1	5
Battery HVAC	5	1	5	3	1	1	1	3	3	3	1	3	3	2	1
Wheel covers - tractors	5	1	3	1	1	5	3	3	3	3	3	3	3	2	1
Remove or relocate any trailer drag parts?	5	1	1	1	1	1	1	1	1	5	1	1	5	1	1
Wide based tires - trailers	5	4	3	3	1	1	3	1	1	5	1	3	3	2	1
Truck Stop Elect via AC Power Port	1	1	5	3	1	1	1	3	1	5	1	1	1	1	1
Clutched Water Pump	2	1	5	3	1	1	1	1	5	3	1	1	5	1	1
Trailer tail fairings	5	2	1	1	1	3	1	1	1	3	5	1	1	1	1
Tire pressure monitoring - tractor	5	5	5	3	1	3	3	1	1	5	2	1	3	1	1
Shift to Neutral	5	3	1	3	1	5	3	1	1	1	1	1	3	1	1
6x2 axles	5	1	1	2	1	1	3	1	1	3	2	3	3	2	3
Engine Start/Stop for HVAC	1	3	1	2	1	1	3	1	5	3	1	1	3	2	1
Two Speed Fan Clutch	1	1	1	1	1	1	3	3	1	3	2	4	1	1	1
CNG	1	1	1	3	2	1	3	1	1	1	5	3	1	5	3
Use of doubles or triples trailers	5	1	1	1	3	1	1	3	1	3	3	3	3	1	5
Automatic transmissions	1	1	1	1	3	2	3	1	1	1	3	3	1	1	1
Diesel APU	1	5	1	2	3	1	3	2	1	1	1	3	1	1	1
Tandem fairings	1	1	3	1	1	5	1	1	1	3	1	1	1	1	1
Use of clutched air compressor	1	1	1	1	1	1	1	1	1	3	5	4	2	6	1
Uses Truck Stop Elect (Snorkel type)	1	1	1	2	1	5	1	1	1	1	1	1	1	1	1
Tire pressure monitoring - trailer		1	1	1	1	1	3	1	1	1	1	3	1	1	1
Trailer nose cones	1	1	1	1	1	1	1	1	1	3	5	1	1	1	1
Wheel covers - trailers	1	1	1	1	1	5	1	1	1	2	1	1	1	1	1
Vortex generators	1	1	1	3	1	1	1	1	1	3	1	1	3	1	1
Move from 6x4 to 4x2 tractor specs	1	1	1	2	1	1	3	1	1	1	3	1	1	1	1
Fuel additives	1	1	1	5	3	1	1	1	1	1	1	1	1	1	1
LNG	1	1	1	3	1	1	1	2	1	1	1	3	1	5	2
Tire pressure inflation - tractor	1	1	1	1	1	3	3		1	1	1	1	1	2	1
Thermal Storage System	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tires filled using Nitrogen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trailer undertray or bogie fairing	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1

Trend Legend	
1	Not Explored
2	Started and stopped
3	On some trucks
4	Slow climb to 100%
5	Fast climb to 100%
6	Part discontinued

Figure 11: Adoption Diversity

This information is available for free as a downloadable spreadsheet with this report. Fleets should use this as a peer benchmarking tool in navigating the many available technologies that can have a positive impact on lowering fuel expenses. Once a fleet has downloaded this chart, a simple method by which fleets could approach this data is:

1. Consider the top third of the table, containing the technologies most commonly adopted by the fleets in this study for specifying on your next tractor and trailer. Ask yourself very specifically, *why are we not buying these technologies?*

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2. Investigate the technologies in the middle third of the table. These technologies likely have less uniformity of adoption by the fleets as they may be more specific to certain duty cycles or business models. At least some of these technologies will also offer good options for you to consider purchasing. Ask, with respect to our fleet, "*why do we think these fleets are not uniform in adoption of these technologies?*"
3. Explore the technologies on the bottom third of the table. Many of these technologies may be new to the market, so they may be likely adoption opportunities down the road. *Ask yourself if any of them offer an opportunity for your fleet to be an innovative early adopter?* Or are they not valuable technologies, yet, and need further development.

5 Efficiency and Purchase Content of Latest Equipment

By 2015, the fleets in this study had adopted many of the 69 technologies, though each fleet has chosen its own unique suite to implement. It is difficult to compare the fuel efficiency of different fleets as they vary in terms of the cargo they haul (weight), the geography and climate they operate in, and their business model for freight movement. Other variables such as driver makeup, company drivers versus independent contractors, length of time they plan to own the equipment, etc. will also have an impact on adoption decisions.

For this study, the fleets provided NACFE with fleet-wide fuel efficiency data, and required that we only publicly share aggregated averages of that data; they did not generally provide data for their equipment by model year. However, during this year's data collection, NACFE did obtain and discuss some of the fuel efficiency results obtained by many of the fleets with respect to their 2016 model year equipment and how they operated in 2015.

This research concludes that these fleets are operating their latest vehicles in a range of 7.8 to 9.0 miles per gallon. Some trucks were even found to approach 9.3 MPG in certain routes, conditions and seasons. This rate of improvement stems from three areas:

- the purchase content of efficiency technologies,
- the fact that the improvements delivered by Diesel Exhaust Fluid-equipped (2010 emission) trucks have reached saturation, and
- most recently the gains from some base engine improvements made in response to the 2014 Greenhouse Gas rule.

Given how high the MPG numbers are for new tractors within this study, it is reasonable to expect similar gains overall gains in future years as older vehicles are replaced with these much more efficient tractors.

6 Fuel Savings from Efficiency Actions

The data on the uptake over time of these technologies, shown earlier, raises many additional questions. Among them:

- What impact do these technologies have on the fuel efficiency of the trucks in the fleet?
- What is the payback on investment in each of these technologies?

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- What were other benefits and consequences of adoption other than the purchase price and fuel savings?

The average adoption percentage and fuel efficiency of these fleets is shown together in Figure 12 below. The MPG shown is for all trucks in the fleet in that year, so it does include tractors and trailers procured in years prior to a fleet's decision to adopt any given technology. It is therefore expected that the fuel efficiency curve will lag the adoption curve by a few years, as older trucks with fewer or none of the technologies installed are phased out.

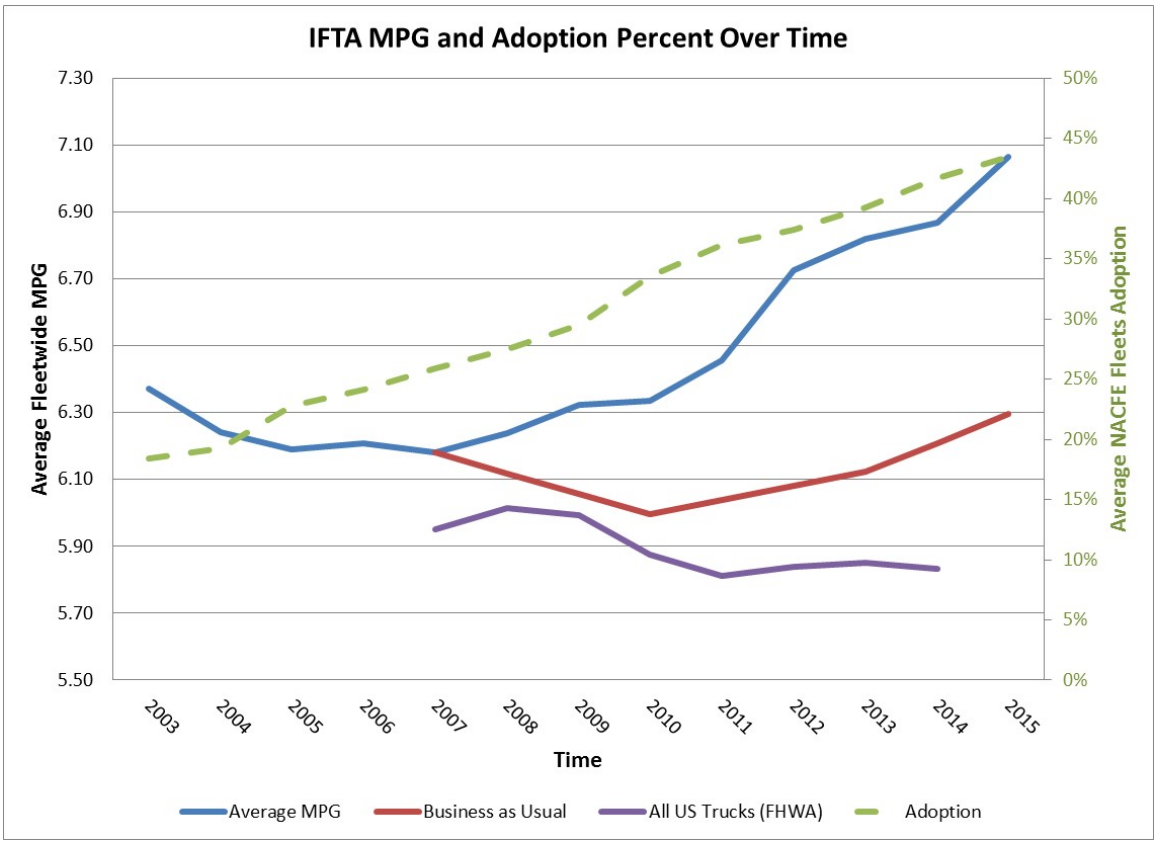

Figure 12: Adoption and MPG over the Study Period

You may note the "U" shape of the Average MPG curve. In the first half of the time period, 2003 to 2010, the impact of the introduction and purchase of engines which met EPA04 and EPA07 emissions level requirements caused an overall decrease in fuel efficiency. In the period between 2007 and 2010, procurement of new fuel economy technologies at these fleets grew and began to stabilize the MPG, overcoming the degrading effect of the new engines. Finally, over the years 2011 to 2015, the average fuel efficiency of NACFE's study fleets improved, due to a dramatic increase in the adoption rates of new fuel efficiency technologies, along with the introduction of DEF in 2010, as well as the 2014 GHG emissions regulations' effects on the base powertrain. In 2015, the fleet wide average MPG of the combined fleet rose 3%, an even higher rate of year-over-year improvement than in 2014, 2013 and 2012. In order to have this single year improvement in fuel efficiency, the equipment put into service in 2015 is

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16% better than the units removed from service, that on average, were 2010 MY, tractors put into service in 2009.

The study team met with a few companies, including fleets in the study, tractor manufacturers and some telematics providers to discuss this improvement in fuel efficiency. The conclusion is that this increase is not surprising and their data basically aligns with it. Factors include:

- 2016MY trucks compared to 2010MY shows that the MPG benefited from movement to EPA2010 systems using Diesel Exhaust Fluid, the 2014 GHG phase 1 products and the year-over-year increase in adoption of the technologies included in this study.
- There was a high level of new truck production built in 2015 and put into service by fleets.

One such company, Fleet Advantage analyzes data from thousands of trucks to help their customers be successful. Figure 13 illustrates the most recent information from their Truck Lifecycle Data Index, which shows that the "All in Cost" to operate a 2017 Model Year sleeper tractor was $19,432 less than a 2011 MY tractor. And that the newer model year trucks were 14% more fuel efficient than the older ones. In discussions with the company's data analysts, they concurred that a 16% increase of trucks put into service in 2015 versus those built prior to the 2010 EPA regulations is in alignment with their data (Fleet Advantage, 2016).

Fleet Advantage
DATA DRIVEN SOLUTIONS

TRUCK LIFECYCLE DATA INDEX Q2 2016

Day Cab-"All In" Cost Comparison				
Model Year	Approximate All In Cost	2017 Model Year All in Cost	Savings	Fuel/CO2 Reduced
2011	$69,192	$50,376	$18,816	14%
2012	$64,438	$50,376	$14,062	12%
2013	$60,678	$50,376	$10,302	9%
2014	$59,897	$50,376	$9,521	7%
2015	$56,340	$50,376	$5,964	5%

Sleeper-"All In" Cost Comparison				
Model Year	Approximate All In Cost	2017 Model Year All in Cost	Savings	Fuel/CO2 Reduced
2011	$71,837	$52,405	$19,432	14%
2012	$67,085	$52,405	$14,680	12%
2013	$63,339	$52,405	$10,934	9%
2014	$62,604	$52,405	$10,199	7%
2015	$59,067	$52,405	$6,662	5%

Figure 13: Cost Improvement Operating Newer Trucks

Ryder System, Inc. manages a very large fleet of Class 8 tractors and has MPG data on over 65,000 units. In consultation with their data experts, the differences in fuel efficiency between pre-2010 level emissions and equipment put into service in 2015, can be up to 32% when comparing similarly equipped trucks in a few specific duty cycles. Fleets are truly experiencing significant improvements in fuel economy with newer equipment.

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The study team also created a "Business as Usual" prediction, to show the likely fuel economy these fleets would have experienced over this time period if they had not adopted any technologies, and solely enjoyed the benefits of the recent base engine efficiency improvements. NACFE's hypothetical BAU scenario in fact maps well against the actual data reported by the U.S. Department of Transportation's Federal Highway Administration (FHWA) for the approximately 1.7 million over the road tractor trailers operating in the United States. This complete set of trucks lags the NACFE fleets as they tend to run older equipment, in some cases purchasing their tractors from the fleets in this study. They also tend to lag in pursuing the technologies to improve fuel economy.

The fuel savings in 2016 between the BAU of 6.30 MPG and the NACFE fleets average of 7.06 MPG amounts to $4,653 per year per truck, at the $2.71 per gallon fuel cost over the average tractor mileage of 99,958. The fleets are saving $8,075 over the national average of 5.83 MPG. If fuel costs had been at the 4-year average of $3.89 per gallon the savings would have been $6,679 and $11,591, respectively. And finally, for these 17 fleets operating 62,123 trucks, in 2015 combined they saved $500,635,787 compared to the average trucks on the road.

A simple analysis was conducted on the payback of the technologies that provide the majority of the savings for these fleets. That review determined about a 2.5-year payback for those technologies. This payback will improve in the future as higher adoption leads to lower upfront purchase prices. The value of these technologies is discussed further in this report.

7 Trucking Efficiency Confidence Reports

The learnings from these Annual Fleet Fuel Studies provide useful insights into adoption trends in the industry, as well as into the specific practices of different major fleets. NACFE hopes that this information alone will spur additional investment, particularly by fleets that may be lagging behind the overall industry when it comes to certain widely-adopted technologies. However, in the course of conducting the study, it became clear that some technologies are still only being adopted by the most progressive or innovative fleets in spite of their showing strong potential for achieving cost-effective gains in fuel efficiency. In order to facilitate the wider industry's trust in and adoption of such technologies, NACFE and CWR formed Trucking Efficiency and began a series of reports, called "Confidence Reports," which take an in-depth look at those most-promising but least-adopted technologies one-by-one.

Confidence Reports provide a concise introduction to a promising category of fuel efficiency technologies, covering key details of their applications, benefits, and consequences. The reports are produced via a data mining process that both combs public information and collects otherwise-private information (which is shared with Trucking Efficiency for the purpose of the reports). This information from manufacturers, end user fleets, tractor and trailer builders and others such as government and non-government organizations is aggregated in order to centralize an unparalleled range of testing data and case studies on a given technology set. All this information including tools for decision making can be found at www.truckingefficiency.org.

As of the release of this report, the group has finished in-depth work in tire pressure systems, 6x2 axles, idle reduction solutions, electronically controlled transmissions, optimizing engine parameters, low rolling resistance tires, downspeeding, lightweighting, maintenance for fuel economy, tractor and trailer aerodynamics, low viscosity engine lubricants and one on determining efficiency. Reports in process

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include one on two-truck platooning and variable engine accessories. Contact us to get involved in this important work.

Figure 14: Trucking Efficiency Confidence Reports

8 Value of Technology Adoption

Each technology has a unique total cost of ownership and return on investment. Trucking Efficiency's series of Confidence Reports provide insight into each technology's primary benefits and consequences, and in most cases organizes the findings into a suggested payback calculation, delivered along with a transparent payback calculator tool, for fleets to plug-in their own specific metrics for improved decision making.

Some technologies such as automated manual transmissions and diesel auxiliary power units do cost thousands of dollars, but they offer significant benefits, and therefore possibly acceptable paybacks. Other technologies such as vented mudflaps or wheel covers cost little, while others such as optimizing engine parameters or choosing light-colored exterior paint cost nothing at all. For each technology studied, the team offers a confidence matrix. Figure 15 shows an example of such a matrix from the Confidence Report on Low Viscosity Engine Lubrication technologies. These graphics locate the technology in question on a grid comparing simple payback in years (value) against the amount of information and performance data available (confidence rating). Fleets should have high confidence in immediately pursuing technologies in the upper right quadrant, as those technologies have a short payback and are well-proven to impact their operations in a very positive manner. Technologies to the top and left of the matrix are those for which there may not be a significant amount of information available, but what data is available suggests they would be very good for most fleets. As more information

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becomes available to the Trucking Efficiency team these ratings and the information on the online Tech Guide will be updated.

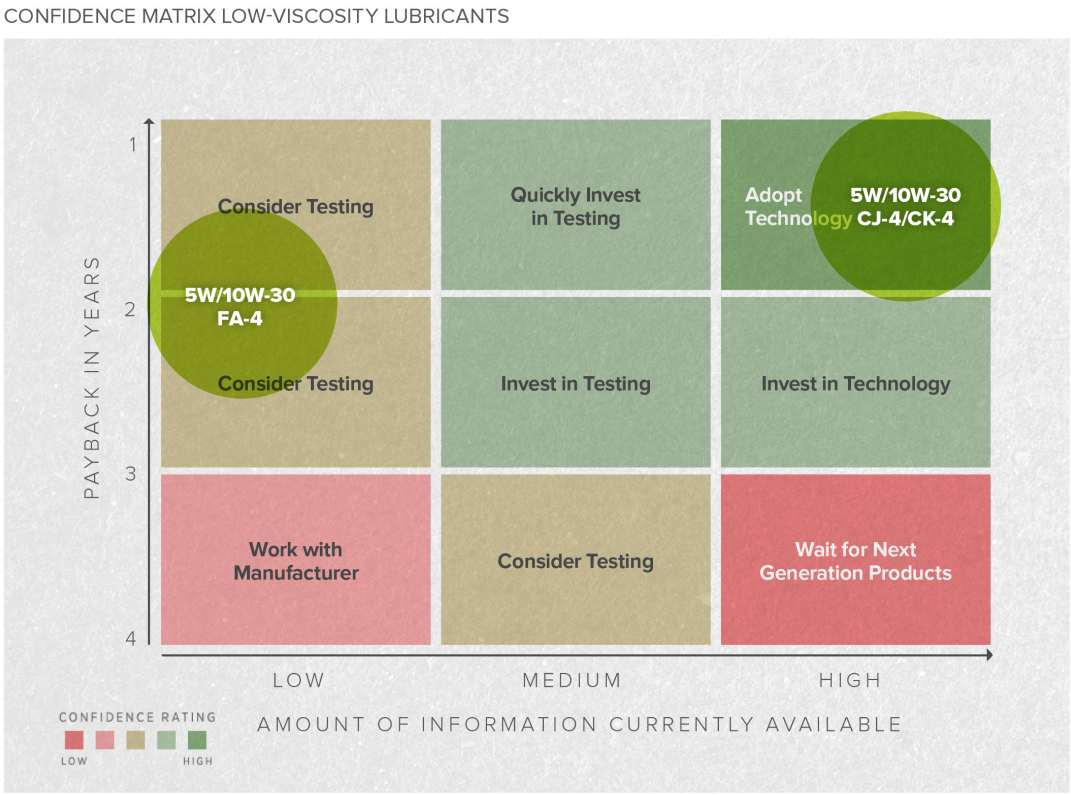

Figure 15: Confidence Matrix for Low-Viscosity Lubricants

9 Study Highlights

With so much data available there are many items of note, but three stood out to the study team for sharing. First, even these 17 fleets varied in the choices they make in fuel efficiency solutions, starkly shown in their adoption of Idle Reduction solutions. Some fleets are using diesel APUs, others electric HVAC systems and others automatic start stop and some managing idle with engine parameter settings, diesel fired heaters and driver training and incentives. Second, the proposed EPA and NHTSA Greenhouse Gas and Fuel Efficiency Regulations estimate a longer term adoption of various technologies that are able to be compared to the adoption by these fleets. This demonstrates the improvement needed in the total cost of ownership or payback needed for these technologies to be valued and purchased by fleets. And

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finally, the study team will share some interesting facts about truck productivity even in the face of lower miles driven per truck.

9.1 Dissimilar Fleet Adoption

In section 4.3, the disparity in adoption by fleets is shown for all technologies in this study. In analyzing the results of this year's data, one set of technologies showed how these fleets differ in the choices they are making on one particular area – idle reduction solutions.

Sleeper tractors in particular, have a unique idling dilemma. Drivers of these trucks commonly sleep, work and rest in the sleeper berths of their big rigs. This requires energy to power such items as air conditioning in the summer, heating in the winter and power for items such as refrigerators, televisions, computer and phone charging, sleep apnea devices, etc. Historically, trucks idled as much as 50% of the time to meet this function while stopped. NACFE studied this extensively and published a very thorough confidence report on more than 19 solutions to lower the idling of sleeper tractors to save fuel and emissions, both exhaust and noise. The report can be viewed here - http://www.truckingefficiency.org/idle-reduction.

In that study, the team concluded that there were five common fleet solutions for sleeper tractor idle reduction shown below in Figure 16. The most minimal equipment intensive was a fleet adding a diesel fired heater, optimizing idle reduction engine parameters and working with the driver to limit the amount of idling, including financial incentives to do so. Next were three approaches that added an anchor technology such as a diesel auxiliary power unit, an electric HVAC system or automatic start stop, where the engine starts every so often to use the cab air conditioning to cool the cab and then shuts itself off. Finally, for particular applications, the use of truck stop electrification is an excellent solution.

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Figure 16: Common Idle Reduction Solutions

In 2015, the fleets in this Annual Fleet Fuel Study differed widely on the approach they used to limit their sleeper tractor idling. The results are as follows:

- All fleets are setting idle reduction engine parameters and all but one, are employing diesel fired heaters.
- One fleet is buying 100% of their tractors with a diesel APU and three more are buying a percentage of their trucks with them. Two had stopped using diesel APUs after having bought them on 100% of their trucks during a prior year.
- Two fleets were employing electric HVAC systems on all the new tractors they put into service in 2015 and another six were putting them on some, but not all of their new trucks. One fleet had been at 100% and has now moved to zero.
- Start stop was being used 100% by one fleet and at a lower percentage on another four fleets, with two fleets having moved away from the start stop solution.
- Finally, two fleets were not using diesel APUs, electric HVACs or start stop systems.

The adoption curves for these technologies are shown in Figure 18. A few specific comments were received from some fleets concerning their particular decisions. They include:

- Region where their trucks predominately operate. If air conditioning demand is lower, some fleets see using a diesel fired heater, electronic controls and driver incentives as sufficient.
- Driver attraction and retention can be improved with the flexibility and performance of a diesel APU.

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- Some fleets are focused on what they believe the longer term solution might be in electric HVACs and making their trucks truck stop electrification plug-in capable.
- And even others like the idea of automatically starting and stopping a truck.

This seems to be an example where many different variables determine a fleet's best technology solution.

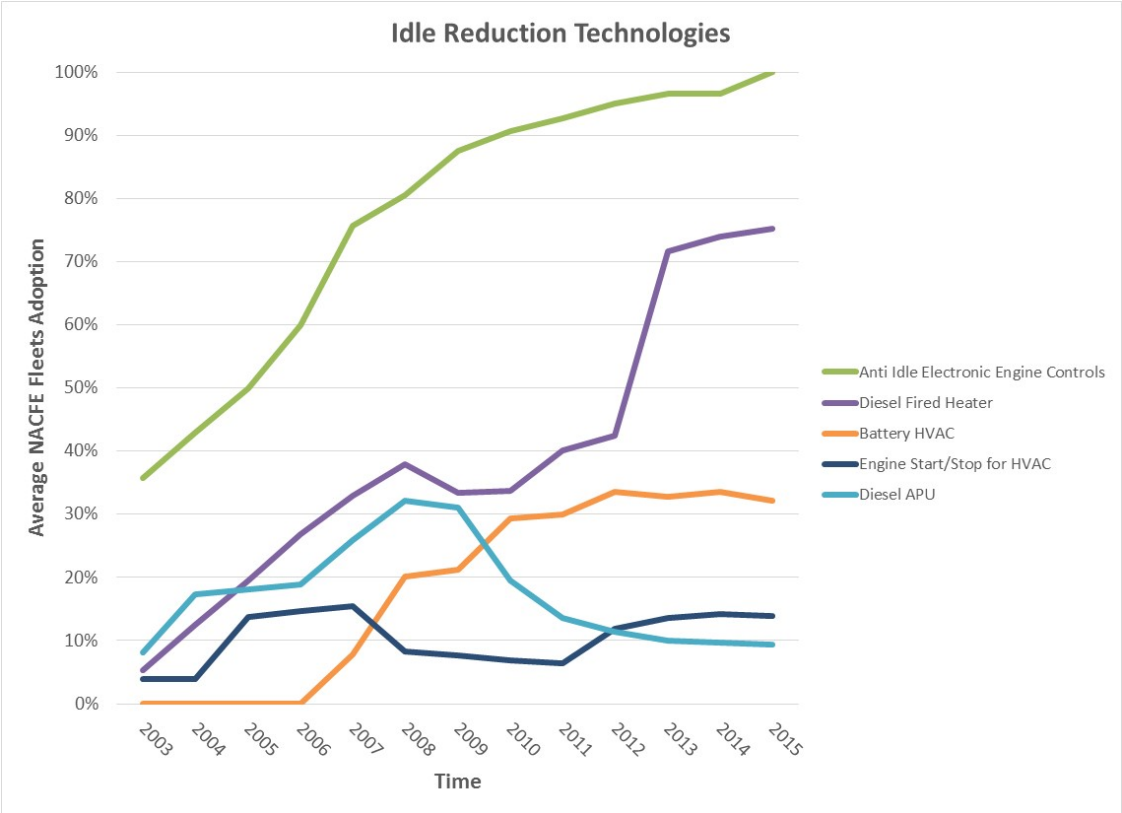

Figure 17: NACFE Fleets Adoption of Idle Reduction Technologies

9.2 Technology Adoption and the Final Greenhouse Gas Rule

On August 16, 2016, the US Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NSTHSA), jointly published the final rule for the Phase 2 of Greenhouse Gas regulations for commercial vehicles, Classes 3 to 8. The rule finalized reductions in fuel use by requiring truck, engine and trailer manufacturers to sell equipment that emits lower emissions via improved fuel economy (EPA, 2016). The International Council for Clean Transportation (ICCT), represented both the Phase 1 and proposed Phase 2 stringency in Figure 18, where the bottom two blue lines represent the tractor and trailer configurations that match the equipment in this Annual Fleet Fuel Study. The lines show that over the 20 years from a base of 2010, Class 8 sleeper tractor trailers will improve their fuel efficiency by about 45%.

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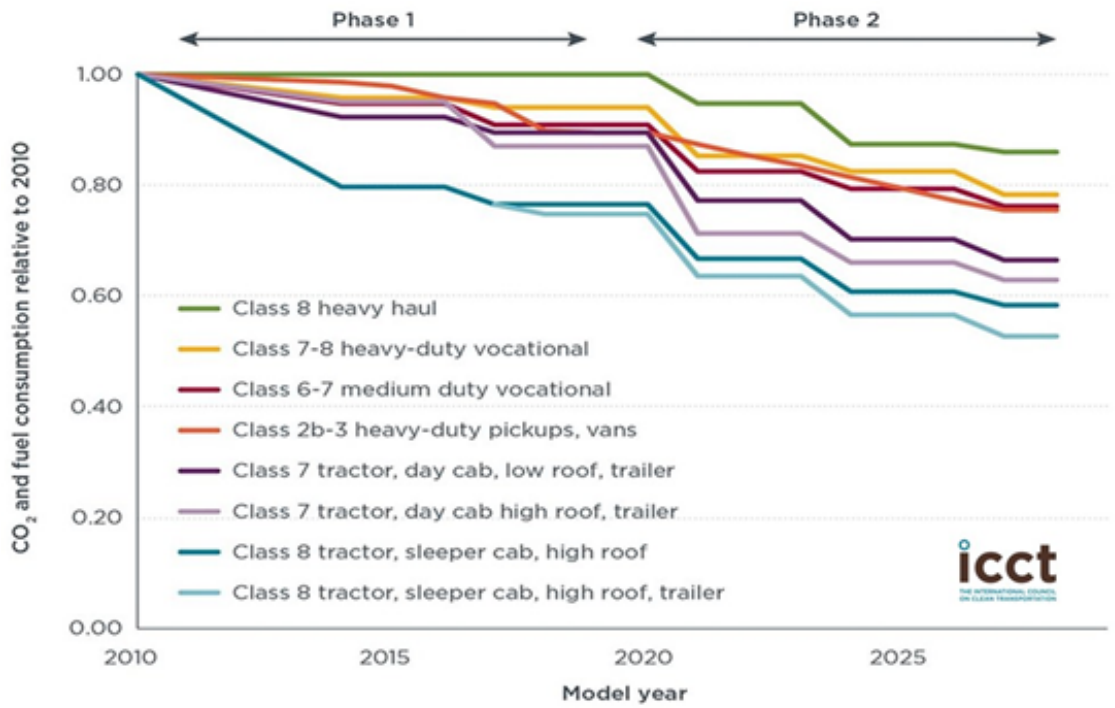

Figure 18: Proposed Greenhouse Gas Phase 2 Stringency (ICCT, 2015)

In the Regulatory Impact Analysis (RIA) included in the final rule, the agencies forecast the potential adoption levels for various technologies that would deliver the stringency identified. Some of these technologies, such as diesel APUs and electric HVAC systems, automatic tire inflation systems, electronically controlled transmissions and 6x2 axles, are included both in the RIA directly and in this study. This gives an opportunity to compare the past, real-world adoption levels from this study at these fleets, to the agencies' predictions of adoption levels by all new trucks for all customers, built in future years. For many technologies such as tires and aerodynamics, it is not possible to compare the two studies as the technologies are described in different ways. For example, the rule shares the percent of new tires at various rolling resistance levels, but that data is not available publicly on tires purchased by fleets.

The following curves (Figures 19-22) show the 2016 Annual Fleet Fuel Study (AFFS) adoption levels on the left, years 2003 to 2015, and on the right the anticipated adoption levels from the agencies for years 2018 (trailers) and 2021 (tractors) to 2030. It is important to note that the current adoption levels for these technologies within the AFFS fleets is likely higher than for the current industry at large.

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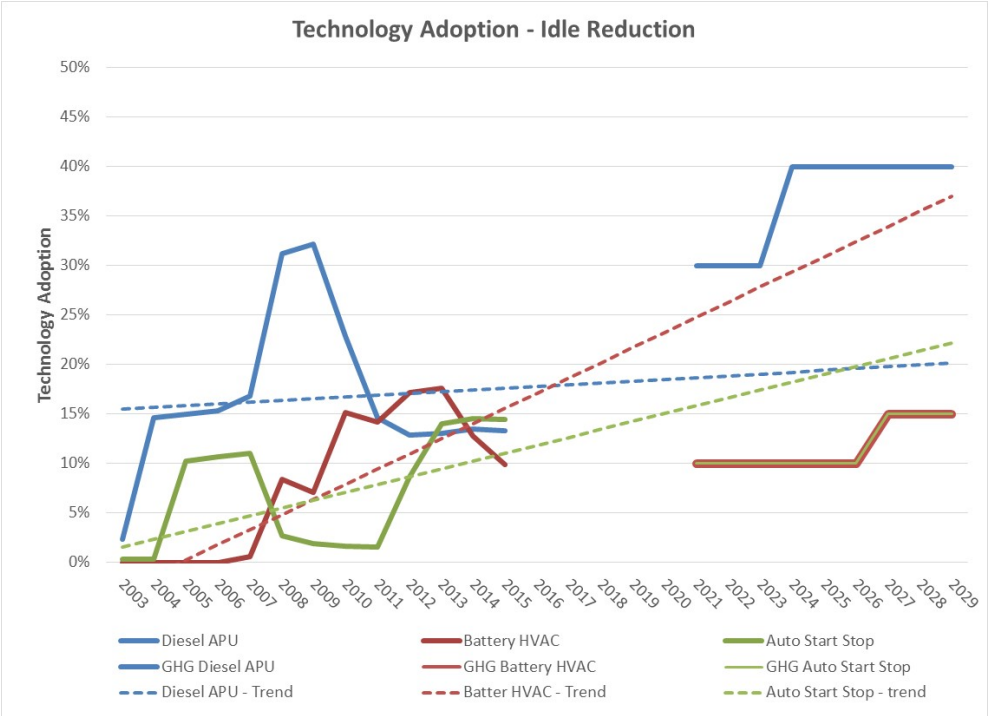

Figure 19: Idle Reduction Adoption - Fleets and GHG Forecast

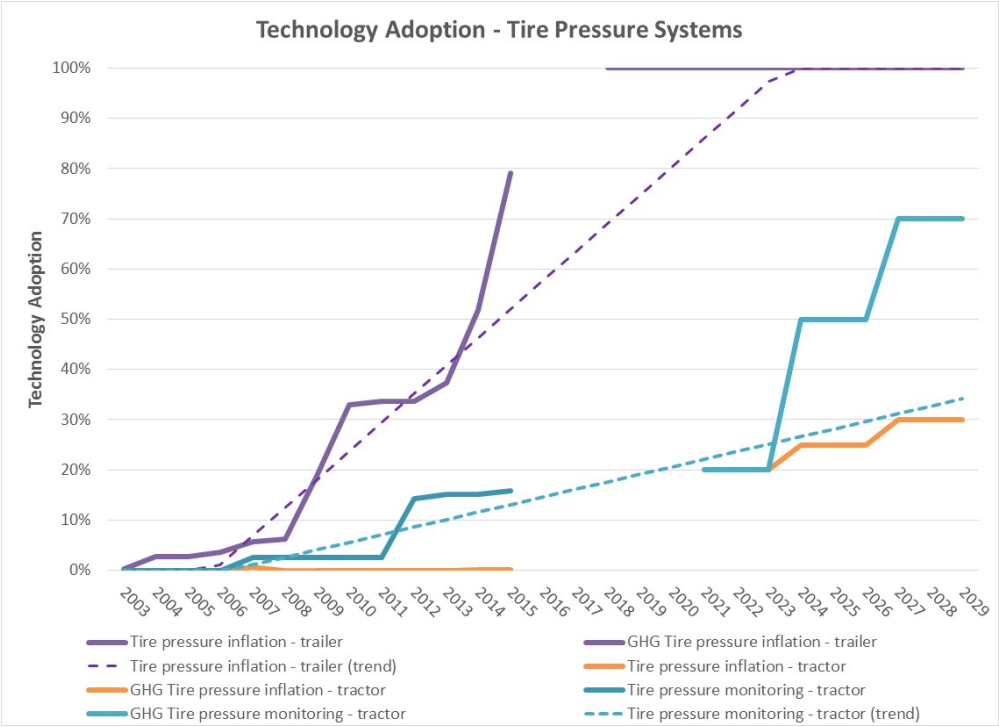

Figure 20: Tire Pressure Systems Adoption - Fleets and GHG Forecast

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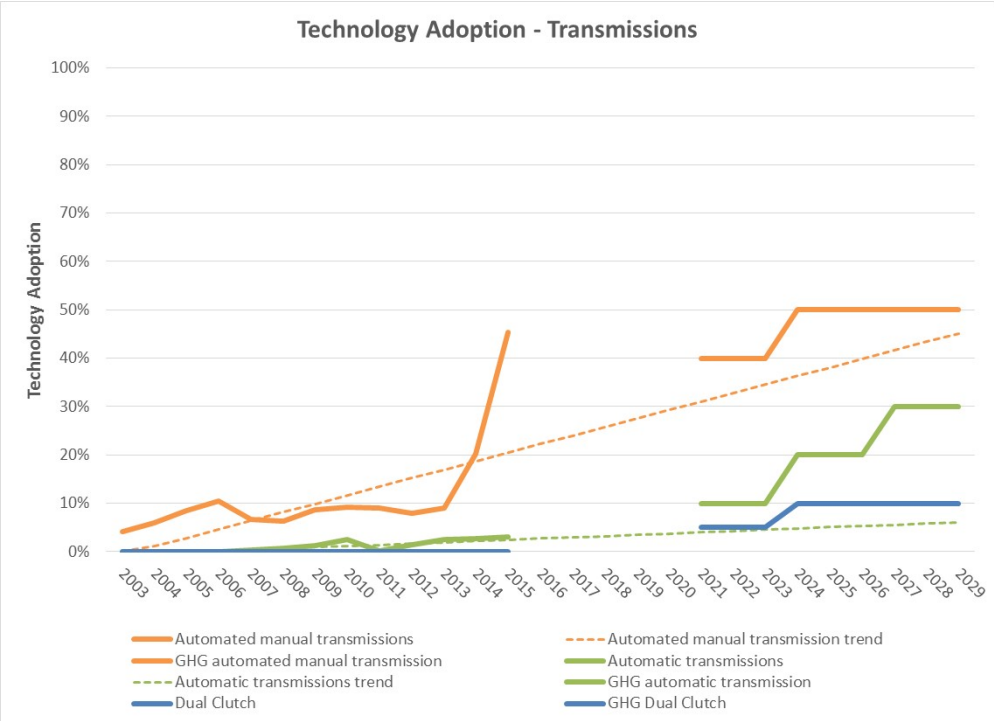

Figure 21: Transmissions Adoption - Fleets and GHG Forecast

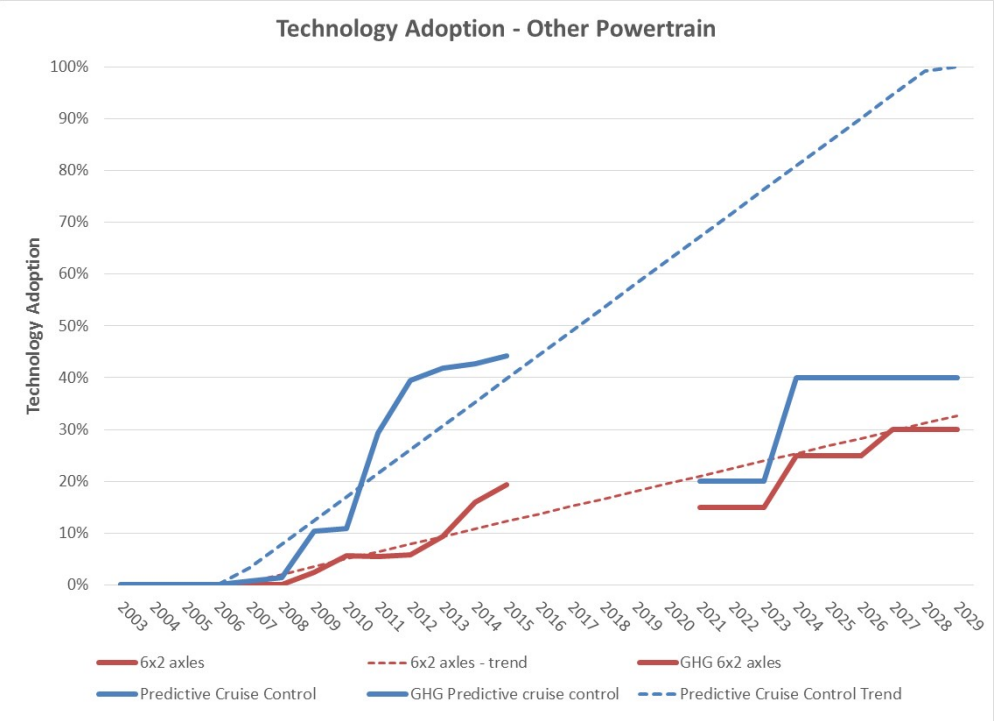

Figure 22: Other Powertrain Adoption - Fleets and GHG Forecast

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In most cases there is a significant gap between the current level of adoption of these forward thinking, early adopting fleets to the full industry adoption levels in future years. There is much work for the industry to do in order to improve confidence in the technologies for increased adoption and for the improvement in the total cost of ownership for these fleets to buy them at the levels expected by the regulators and required of the truck and trailer builders. Fleets in the study expect at least a two-year payback on these technologies (NACFE Barriers, 2014) and will continue to drive manufactures to improve their products. There is time for the industry to deliver these products, but we must be innovative and diligent. There will be more on this from NACFE as the rule becomes finalized later this year and development plans mature to meet the rule.

9.3 Productivity and Miles Driven Annually per Truck

After five years of collecting this data, the study team noticed an interesting trend of fewer miles driven annually per truck and began asking a few questions and investigating items surrounding general truck productivity.

In working with ACT Research (www.actresearch.net), which analyzes a significant amount of data for the trucking industry, they offered an interesting measure of truck productivity that they have been studying for some time. The American Trucking Association (www.trucking.org) reports both tonnage and loads shipped on a monthly basis. In Figure 23, ACT has plotted these two indices on the same graph. From 2003 through 2009, they essentially followed one another, but during the recent downturn or recession in 2009 through 2011, fleets seemed to increase their truck productivity. More tonnage was being hauled with less loads and this trend continues and even widens through 2016. This suggest a 20% plus improvement in goods hauled per load.

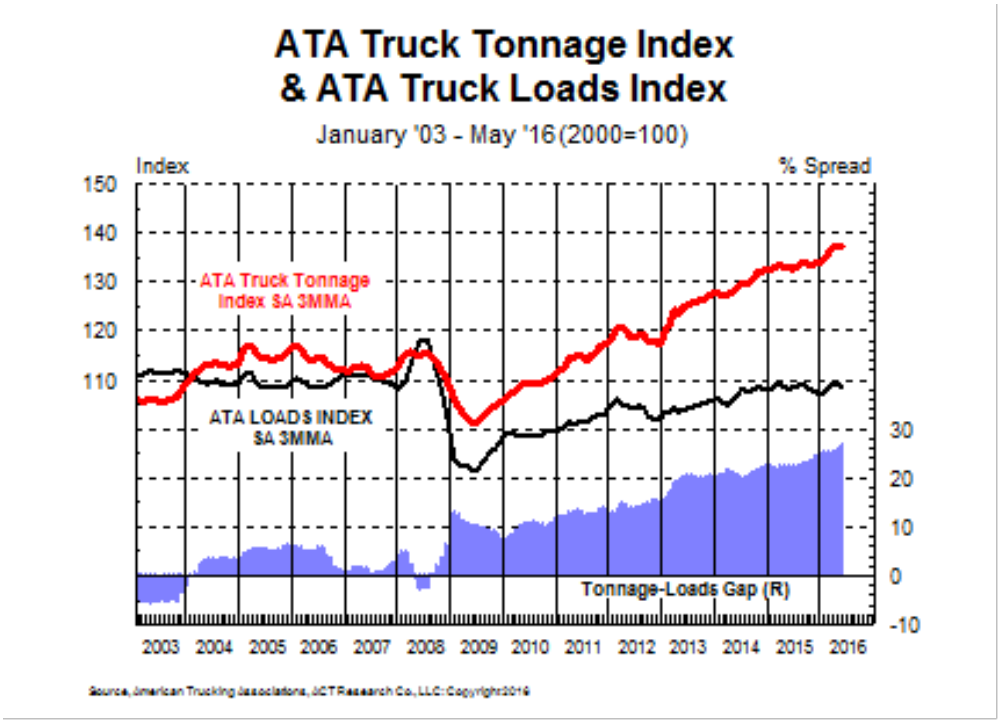

Figure 23: ATA Tonnage and Loads Indices via ACT Research

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In interviewing others for various studies over the years and specifically reported in NACFE's Confidence Report on Lightweighting, free to download at http://www.truckingefficiency.org/tractor-aerodynamics/weight-reduction-tractors, a number of factors may be contributing to this efficiency improvement.

- Freight becoming denser, for instance, tighter packaging on the products,
- More pallets are being hauled in each trailer per mile,
- Private fleets report less empty backhaul miles,
- Telematics help carriers know where their equipment is to be able to pick up more freight,
- Third party logistics are maturing,
- And other strategies.

This increase in productivity moves more freight per load increasing ton-miles or cubic-miles per gallon. This report is focused on miles per gallon as that is the most direct measure available because the amount of freight hauled on each route is not a readily accessible metric at this time.

At this same time, and counter to this improving productivity, the truckload fleets, those operating sleepers, in this study reported a reduction in miles traveled over the last five years from an average of 112,412 to 109,800, which doesn't seem like a large reduction. But, many manufacturers cite average mileage per year for sleeper tractors to be in the range of 120,000 miles or more, when promoting the advantages of their technologies in typical payback calculators. When including all fleets in the AFFS, in other words adding all daycab tractors, the average miles per tractor in 2015 reduced to 99,958.

Fleets shared the following reasons why they believe that their tractors are driving fewer miles annually.

- Expanded use of Electronic Logging Devices (ELDs) which remove the manual calculations of Hours of Service,
- Increasing demands on the driver that limit their driving time. These include increased paperwork, more complex equipment to inspect, etc.
- Longer wait times for freight, for example when loading or unloading at a dock,
- Insufficient truck parking at truck stops or rest areas so drivers need to stop early or drive around to find spots during their Hours of Service,
- Increased congestion lowering average speed during the route, lowering miles.
- Movement of some freight to rail, particularly in long haul routes.

ACT Research also shared with NACFE data from their Truckload Carriers Index. This work uses available public information from fleets to understand trends for the industry. That index is shown Figure 24 detailing Class 8 tractor mileage per year for the past two decades with a linear trend line added. This shows a reduction in miles traveled from around 123,000 in 1996 to about 111,000 in 2015. The AFFS fleets reported average miles per tractor for the five years of the study that mapped well to the ACT Research data.

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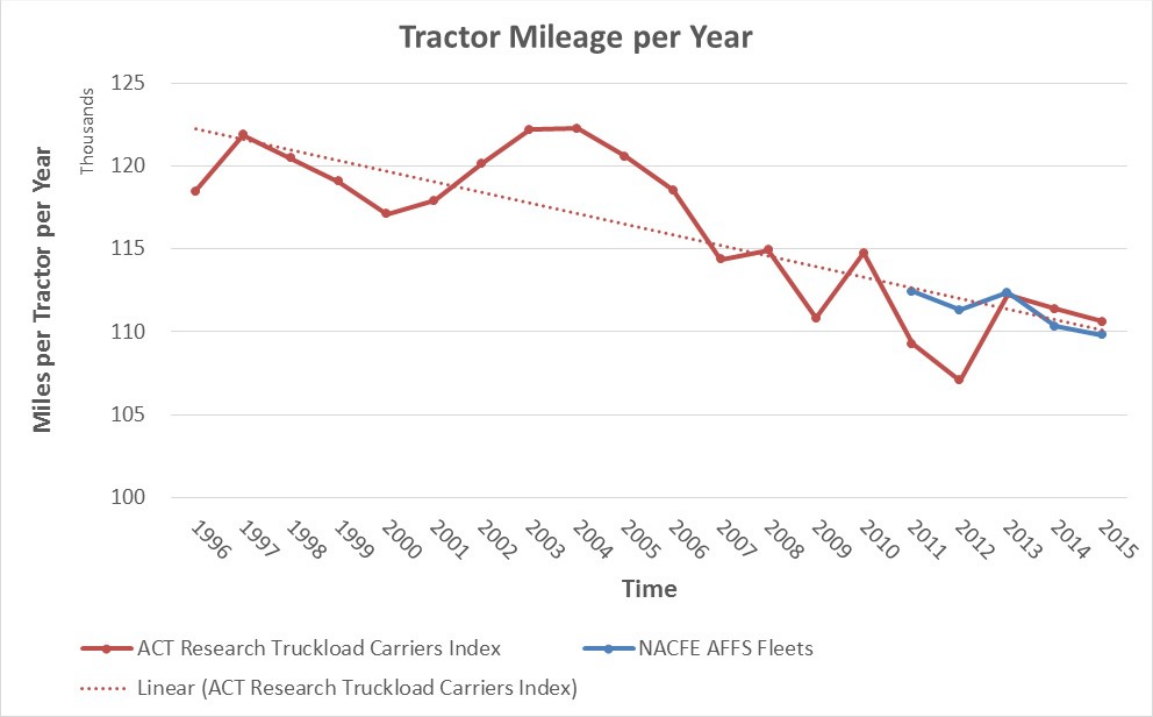

Figure 24: Class 8 Tractor Mileage per Year

This is important as the fleets will use their average miles per tractor in their payback calculations to decide if they should adopt a particular technology. And manufacturers will assume miles per tractor in their product planning target cost calculations. NACFE suggests that manufactures use an assumption close to 110,000 miles for sleepers and 80,000 for daycabs, to accurately reflect the fleets actual use.

10 Conclusion

The results of this annual survey clearly reflect a growing use of fuel savings systems and procedures. However not all fleets operate under the same philosophies and operation conditions so strategies and results differ from fleet to fleet. NACFE (in conjunction with Trucking Efficiency) conducts a series of workshops that allow fleets, dealerships and industry suppliers to gather in an environment of open discussions regarding these industry changes. NACFE realizes that printed materials alone are not the entire answer and personal interface opportunities are also valuable to the industry. Information on upcoming workshops can be found under the "Events" section of the truckingefficiency.org website as well as the NACFE pages on LinkedIn and Facebook. If your fleet would like direct contact, please send a message to david.schaller@nacfe.org.

NACFE would like to thank the participating fleets for offering such important information to the rest of the industry. This study provides a benchmarking opportunity for those fleets to continue to improve the operations and increase freight efficiency. If you are interested in joining this study, please contact the North American Council for Freight Efficiency. For other fleets, serving our population by moving the goods around that we require for our quality of life, the details in this study will provide a roadmap for your consideration of technologies and practices to help reduce fuel costs.

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11 References

(Truck News, 2012), "NACFE conducts extensive benchmarking study on fleet fuel efficiency," Truck News, February 21, 2012.

(EIA, 2016), United States Energy Information Administration, http://www.eia.gov/petroleum/gasdiesel/ , accessed July 28, 2016.

(FHWA, 2016), Federal Highway Administration http://www.fhwa.dot.gov/policyinformation/statistics/2014/vm1.cfm , July 8, 2016.

(ATRI, 2016), American Transportation Research Institute, "An Analysis of the Operational Costs of Trucking: 2015 Update", http://atri-online.org/2015/09/29/an-analysis-of-the-operational-costs-of-trucking-2015-update/, accessed June 24, 2016

(EIA Outlook, 2016), Energy Information Administration's Short-term Energy Outlook http://www.eia.gov/forecasts/steo/ , accessed August 8, 2016.

(FleetAdvantage, 2016), FleetAdvantage, https://www.fleetadvantage.com/Fleet-Advantage-Releases-Q2-2016-Truck-Lifecycle-Data-Index/144, accessed July 26, 2016

(EPA, 2016), United States Environmental Protection Agency, Proposed Greenhouse Gas Regulations, https://www3.epa.gov/otaq/climate/regs-heavy-duty.htm, accessed August 18, 2016.

(ICCT, 2015), International Council for Clean Transportation, "United States Efficiency and Greenhouse Gas Emission Regulations for Model Year 2018-2027 Heavy-Duty Vehicles, Engines and Trailers," http://www.theicct.org/sites/default/files/publications/ICCT-update_US-HDV-Ph2-NPRM_jun2015_v2.pdf

(NACFE Barriers, 2014), "Barriers to the Increased Adoption of Fuel Efficiency Technologies in the North American On-Road Freight Sector", NACFE, ICCT, 2013, http://nacfe.org/wp-content/uploads/2014/03/ICCT-NACFE-CSS_Barriers_Report_Final_20130722.pdf

(NACFE, 2014), North American Council for Freight Efficiency, 2014 Fleet Fuel Study, which includes prior information on best practices of adoption at the fleets. http://nacfe.org/wp-content/uploads/2014/09/NACFE-2014-Study-Report-FINAL-083114.pdf

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12 Appendices

A full set of data is also available for download free at
http://www.truckingefficiency.org/resources

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12.1 Appendix A: Adoption of Technologies by Fleets

Adoption by each technology over the years valuing each fleet's decision equally

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Idle Reduction													
Highest level of cab insulation	0%	0%	7%	7%	7%	10%	14%	16%	17%	19%	39%	47%	48%
Anti Idle Electronic Engine Controls	36%	43%	50%	60%	76%	81%	88%	91%	93%	95%	97%	97%	100%
Diesel Fired Heater	5%	13%	20%	27%	33%	38%	33%	34%	40%	42%	72%	74%	75%
Diesel APU	8%	17%	18%	19%	26%	32%	31%	19%	14%	11%	10%	10%	9%
Battery HVAC	0%	0%	0%	0%	8%	20%	21%	29%	30%	34%	33%	34%	32%
Engine Start/Stop for HVAC	4%	4%	14%	15%	15%	8%	8%	7%	6%	12%	14%	14%	14%
Truck Stop Elect via AC Power Port	0%	0%	0%	0%	0%	8%	15%	15%	15%	15%	15%	16%	22%
Uses Truck Stop Elect (Snorkel type)	0%	2%	2%	3%	5%	5%	3%	0%	0%	0%	0%	7%	7%
Thermal Storage System	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Chassis													
6x2 axles	1%	1%	1%	1%	1%	1%	4%	13%	15%	15%	18%	17%	16%
Synthetic axle lube	67%	67%	73%	80%	80%	87%	87%	93%	94%	94%	94%	97%	98%
Two Speed Fan Clutch	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	13%	12%	12%
Clutched Water Pump	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	25%	22%
Use of clutched air compressor	0%	0%	0%	0%	0%	0%	7%	10%	10%	10%	11%	12%	8%
Move from 6x4 to 4x2 tractor specs	2%	2%	3%	3%	3%	3%	3%	3%	3%	4%	6%	7%	5%
Tires / Rolling Resistance													
Tire pressure inflation - trailer	1%	7%	7%	10%	20%	17%	31%	38%	40%	40%	42%	56%	74%
Tire pressure inflation - tractor	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Tire pressure monitoring - trailer	0%	0%	0%	0%	0%	0%	0%	8%	8%	8%	7%	7%	7%
Tire pressure monitoring - tractor	0%	0%	0%	0%	7%	7%	7%	7%	7%	14%	19%	19%	20%
LRR duals - tractors	22%	22%	27%	27%	32%	37%	30%	44%	43%	50%	53%	53%	52%
LRR duals - trailers	30%	30%	35%	35%	40%	45%	45%	51%	57%	64%	66%	72%	67%
Wide based tires - tractors	0%	13%	13%	14%	17%	17%	23%	37%	43%	48%	45%	43%	44%
Wide based tires - trailers	7%	1%	7%	7%	8%	9%	10%	29%	31%	31%	28%	22%	25%
Tires filled using Nitrogen	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aluminum wheels tractors	53%	53%	61%	67%	67%	75%	72%	74%	79%	85%	85%	86%	87%
Aluminum wheels trailers	21%	15%	21%	22%	22%	23%	32%	52%	54%	52%	54%	54%	54%
Powertrain													
Automated manual transmissions	9%	14%	14%	27%	25%	25%	31%	33%	32%	30%	28%	41%	55%
Automatic transmissions	0%	0%	0%	0%	1%	2%	4%	7%	1%	4%	7%	8%	10%
Direct drive transmission	20%	19%	17%	16%	15%	17%	26%	36%	51%	47%	50%	47%	41%
Synthetic transmission oil	67%	67%	73%	73%	80%	86%	81%	87%	87%	87%	93%	94%	94%
Downsize engine (e.g. 15L - 13L)	9%	9%	12%	9%	12%	5%	8%	20%	41%	50%	50%	54%	52%
Engine parameters set for fuel economy	62%	62%	68%	82%	88%	94%	94%	94%	96%	96%	98%	99%	99%
Shift to Neutral	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	5%	19%
Predictive cruise control	0%	0%	0%	0%	2%	4%	13%	18%	27%	31%	31%	31%	37%
Downspeeding (Rear ratio<2.7:1)	29%	28%	27%	25%	31%	36%	43%	51%	61%	56%	61%	66%	67%
Fuel additives	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	3%	3%	3%
Lower viscosity engine oil xW-30	7%	7%	10%	14%	14%	14%	14%	27%	34%	31%	33%	46%	64%
CNG	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	5%	7%	11%
LNG	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	0%
Tractor Aerodynamics													
Aero hoods and fenders	63%	68%	86%	88%	91%	93%	96%	100%	100%	100%	100%	100%	100%
Aerodynamic bumpers	52%	55%	78%	82%	86%	89%	91%	96%	100%	100%	100%	100%	100%
Aerodynamic mirrors	62%	66%	85%	88%	92%	94%	98%	100%	100%	100%	100%	100%	100%
Full height roof air fairing	71%	72%	80%	82%	82%	89%	90%	91%	94%	96%	95%	95%	95%
Tandem fairings	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	9%
Remove parts - bug deflectors, etc.	35%	35%	37%	37%	39%	39%	49%	58%	60%	60%	63%	62%	62%
Tractor chassis skirts - full	28%	30%	41%	43%	51%	54%	65%	72%	63%	68%	68%	72%	73%
Tractor chassis skirts - partial	32%	34%	39%	41%	37%	39%	38%	41%	35%	29%	30%	33%	39%
Fixed 5th wheel w/ minimum gap	31%	32%	45%	43%	43%	43%	48%	54%	54%	47%	44%	39%	35%
Cab extenders	58%	58%	72%	74%	77%	77%	83%	85%	87%	81%	86%	87%	92%
Wheel covers - tractors	0%	0%	0%	0%	0%	0%	0%	3%	7%	8%	16%	29%	29%
Vented mudflaps - tractors	0%	0%	0%	0%	0%	0%	0%	3%	26%	32%	33%	38%	37%
Trailer Aerodynamics													
Trailer skirts	0%	0%	0%	0%	1%	0%	13%	47%	55%	67%	70%	81%	83%
Use of doubles or triples trailers	7%	7%	7%	7%	8%	8%	8%	8%	8%	8%	9%	10%	10%
Trailer nose cones	0%	0%	0%	0%	0%	0%	0%	7%	7%	7%	6%	6%	6%
Remove or relocate any trailer drag parts?	0%	0%	0%	0%	0%	0%	0%	7%	7%	21%	25%	25%	25%
Vented mudflaps - trailer	0%	0%	0%	0%	0%	0%	0%	2%	27%	31%	29%	34%	34%
Wheel covers - trailers	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	6%
Trailer undertray or bogie fairing	0%	0%	0%	0%	0%	0%	0%	0%	1%	2%	3%	0%	0%
Trailer tail fairings	0%	0%	0%	0%	0%	0%	0%	7%	7%	7%	15%	21%	20%
Vortex generators	0%	0%	0%	0%	0%	0%	0%	3%	3%	4%	4%	5%	5%
Practices													
Limit Speed <65 mph	50%	50%	63%	70%	70%	84%	93%	93%	93%	93%	99%	93%	93%
Specified weight reduction on tractors	28%	30%	42%	47%	47%	47%	47%	54%	62%	63%	59%	59%	59%
Specified weight reduction on trailers	20%	23%	25%	27%	27%	27%	27%	33%	33%	33%	37%	37%	38%
Reduce empty miles	73%	73%	87%	87%	87%	87%	87%	87%	87%	87%	86%	87%	88%
Driver training for fuel economy	73%	73%	80%	80%	80%	80%	80%	80%	93%	93%	95%	93%	95%
Driver incentives for FE	20%	20%	20%	20%	20%	20%	20%	20%	27%	27%	26%	37%	43%
In cab Cameras	27%	27%	27%	27%	20%	20%	20%	20%	20%	20%	20%	22%	35%
Routing optimization	63%	63%	63%	63%	70%	77%	77%	77%	77%	77%	77%	80%	86%
Coasting before engine braking	13%	13%	13%	16%	24%	25%	25%	25%	33%	33%	32%	36%	50%

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12.2 Appendix B: Adoption Scaled by the Number of Miles Driven

Adoption by each technology over the years using miles driven as an estimate of feature uptake

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Idle Reduction													
Highest level of cab insulation	0%	0%	9%	9%	9%	6%	11%	12%	13%	14%	23%	26%	28%
Anti Idle Electronic Engine Controls	33%	41%	50%	68%	72%	83%	81%	85%	88%	90%	95%	95%	98%
Diesel Fired Heater	1%	12%	21%	22%	35%	35%	29%	29%	36%	39%	69%	70%	70%
Diesel APU	2%	15%	15%	15%	17%	31%	32%	23%	15%	13%	13%	13%	13%
Battery HVAC	0%	0%	0%	0%	1%	8%	7%	15%	14%	17%	18%	13%	10%
Engine Start/Stop for HVAC	0%	0%	10%	11%	11%	3%	2%	2%	2%	9%	14%	14%	14%
Truck Stop Elect via AC Power Port	0%	0%	0%	0%	0%	2%	4%	4%	4%	4%	4%	5%	6%
Uses Truck Stop Elect (Snorkel type)	0%	1%	1%	1%	2%	2%	1%	0%	0%	0%	0%	8%	8%
Thermal Storage System	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Chassis													
6x2 axles	0%	0%	0%	0%	0%	0%	2%	6%	6%	6%	9%	16%	19%
Synthetic axle lube	81%	81%	84%	84%	84%	93%	93%	95%	95%	95%	99%	100%	100%
Two Speed Fan Clutch	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	12%	4%	3%
Clutched Water Pump	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	26%	28%
Use of clutched air compressor	0%	0%	0%	0%	0%	0%	3%	5%	5%	5%	6%	6%	3%
Move from 6x4 to 4x2 tractor specs	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	1%
Tires / Rolling Resistance													
Tire pressure inflation - trailer	0%	3%	3%	4%	6%	6%	19%	33%	33%	33%	37%	52%	79%
Tire pressure inflation - tractor	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Tire pressure monitoring - trailer	0%	0%	0%	0%	0%	0%	0%	14%	14%	14%	14%	14%	14%
Tire pressure monitoring - tractor	0%	0%	0%	0%	2%	2%	2%	2%	2%	14%	15%	15%	16%
LRR duals - tractors	25%	25%	30%	30%	34%	35%	34%	62%	61%	63%	70%	71%	71%
LRR duals - trailers	26%	26%	30%	30%	35%	36%	36%	66%	67%	70%	77%	81%	80%
Wide based tires - tractors	0%	7%	7%	7%	9%	9%	10%	24%	28%	33%	31%	27%	27%
Wide based tires - trailers	5%	0%	5%	5%	5%	6%	7%	20%	21%	22%	20%	16%	17%
Tires filled using Nitrogen	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aluminum wheels tractors	62%	62%	64%	65%	65%	73%	67%	69%	74%	76%	80%	80%	80%
Aluminum wheels trailers	16%	12%	16%	16%	16%	17%	29%	34%	36%	37%	37%	36%	36%
Powertrain													
Automated manual transmissions	4%	6%	9%	10%	7%	6%	9%	9%	9%	8%	9%	20%	45%
Automatic transmissions	0%	0%	0%	0%	0%	1%	1%	3%	0%	1%	3%	3%	3%
Direct drive transmission	21%	21%	20%	19%	19%	19%	23%	29%	52%	51%	54%	51%	34%
Synthetic transmission oil	70%	70%	73%	73%	84%	93%	85%	93%	93%	93%	99%	99%	99%
Downsize engine (e.g. 15L - 13L)	4%	4%	8%	4%	5%	2%	5%	10%	36%	42%	44%	47%	47%
ngine parameters set for fuel economy	64%	64%	73%	92%	93%	94%	94%	94%	94%	94%	99%	99%	99%
Shift to Neutral	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	6%	15%
Predictive cruise control	0%	0%	0%	0%	1%	1%	10%	11%	29%	40%	42%	43%	44%
Downspeeding (Rear ratio<2.7:1)	37%	37%	36%	35%	52%	53%	65%	66%	70%	68%	71%	76%	79%
Fuel additives	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	2%	2%	2%
Lower viscosity engine oil xW-30	2%	2%	10%	18%	18%	18%	18%	33%	35%	34%	35%	39%	59%
CNG	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	2%	3%	10%
LNG	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	16%	0%
Tractor Aerodynamics													
Aero hoods and fenders	67%	71%	83%	85%	89%	93%	94%	95%	95%	95%	100%	100%	100%
Aerodynamic bumpers	49%	51%	67%	71%	77%	82%	85%	87%	95%	95%	100%	100%	100%
Aerodynamic mirrors	60%	64%	79%	82%	89%	93%	94%	95%	95%	95%	100%	100%	100%
Full height roof air fairing	81%	81%	83%	83%	82%	91%	85%	86%	91%	93%	96%	96%	96%
Tandem fairings	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	11%
Remove parts - bug deflectors, etc.	33%	33%	33%	33%	34%	34%	37%	38%	39%	39%	43%	43%	43%
Tractor chassis skirts - full	28%	30%	34%	35%	42%	46%	50%	57%	56%	65%	69%	71%	71%
Tractor chassis skirts - partial	28%	30%	33%	35%	34%	38%	39%	40%	38%	29%	28%	30%	35%
Fixed 5th wheel w/ minimum gap	33%	35%	44%	40%	40%	40%	44%	46%	46%	45%	46%	38%	38%
Cab extenders	76%	76%	86%	87%	86%	86%	88%	89%	89%	87%	93%	94%	95%
Wheel covers - tractors	0%	0%	0%	0%	0%	0%	0%	5%	14%	14%	17%	29%	28%
Vented mudflaps - tractors	0%	0%	0%	0%	0%	0%	0%	1%	21%	23%	24%	26%	26%
Trailer Aerodynamics													
Trailer skirts	0%	0%	0%	0%	1%	0%	9%	43%	56%	68%	73%	86%	85%
Use of doubles or triples trailers	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	18%	19%	19%
Trailer nose cones	0%	0%	0%	0%	0%	0%	0%	3%	3%	3%	3%	3%	3%
nove or relocate any trailer drag parts?	0%	0%	0%	0%	0%	0%	0%	16%	16%	20%	31%	31%	31%
Vented mudflaps - trailer	0%	0%	0%	0%	0%	0%	0%	1%	22%	23%	23%	24%	24%
Wheel covers - trailers	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	8%
Trailer undertray or bogie fairing	0%	0%	0%	0%	0%	0%	0%	0%	1%	2%	2%	0%	0%
Trailer tail fairings	0%	0%	0%	0%	0%	0%	0%	1%	2%	1%	13%	21%	14%
Vortex generators	0%	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	3%
Practices													
Limit Speed <65 mph	54%	54%	64%	67%	67%	86%	89%	89%	89%	89%	98%	85%	85%
Specified weight reduction on tractors	22%	22%	26%	29%	29%	29%	29%	33%	46%	46%	37%	36%	36%
Specified weight reduction on trailers	10%	11%	12%	12%	12%	12%	12%	24%	24%	24%	28%	28%	30%
Reduce empty miles	81%	81%	91%	91%	91%	91%	91%	91%	91%	91%	93%	93%	94%
Driver training for fuel economy	81%	81%	90%	90%	90%	90%	90%	90%	94%	94%	96%	96%	96%
Driver incentives for FE	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	20%	37%	37%
In cab Cameras	36%	36%	36%	36%	21%	21%	21%	21%	21%	21%	21%	22%	24%
Routing optimization	60%	60%	60%	60%	73%	83%	83%	83%	83%	83%	86%	94%	95%
Coasting before engine braking	7%	7%	7%	9%	25%	25%	25%	25%	27%	27%	28%	29%	32%

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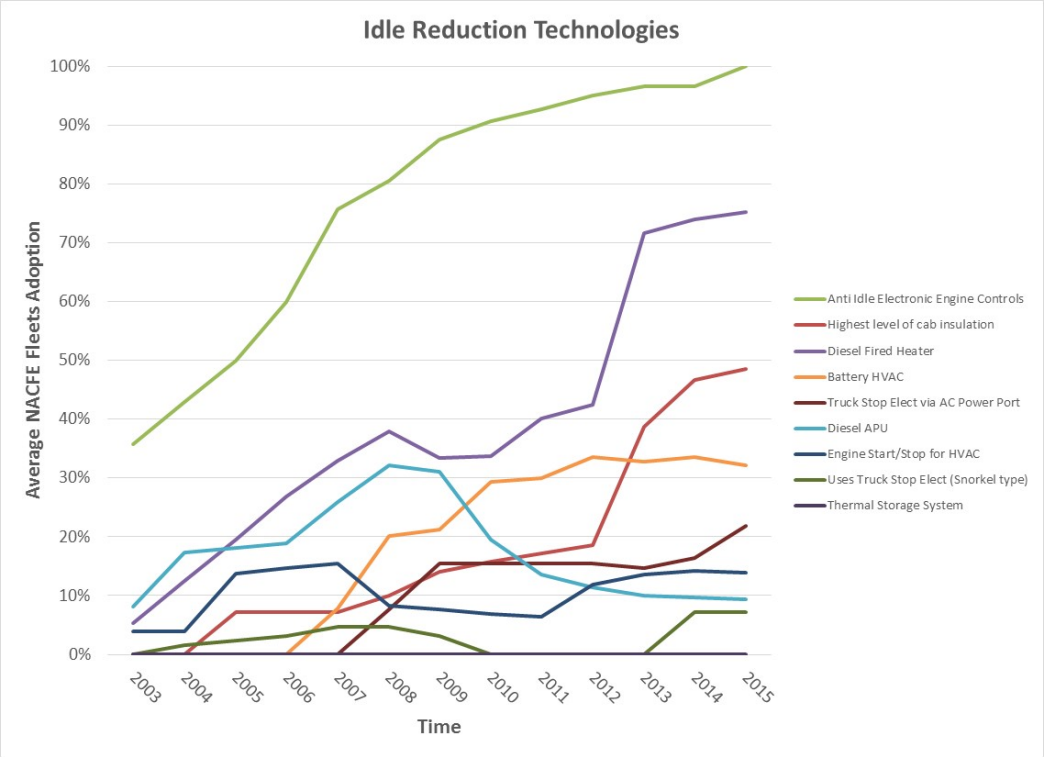
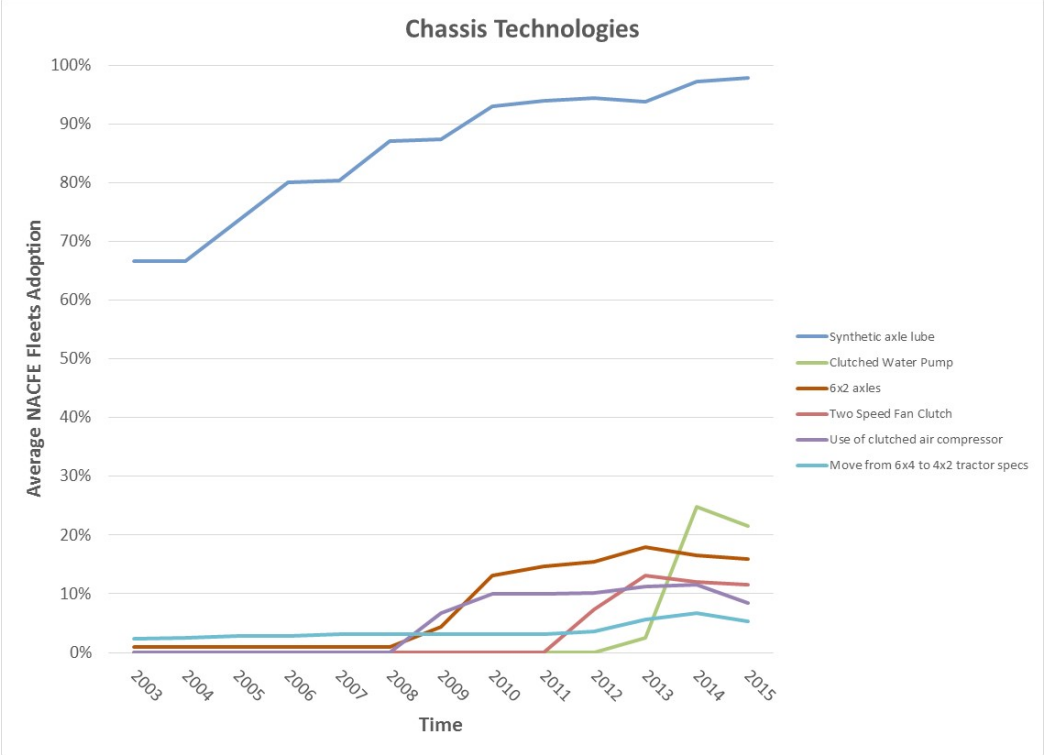
12.3 Appendix C: Adoption Curves by Category





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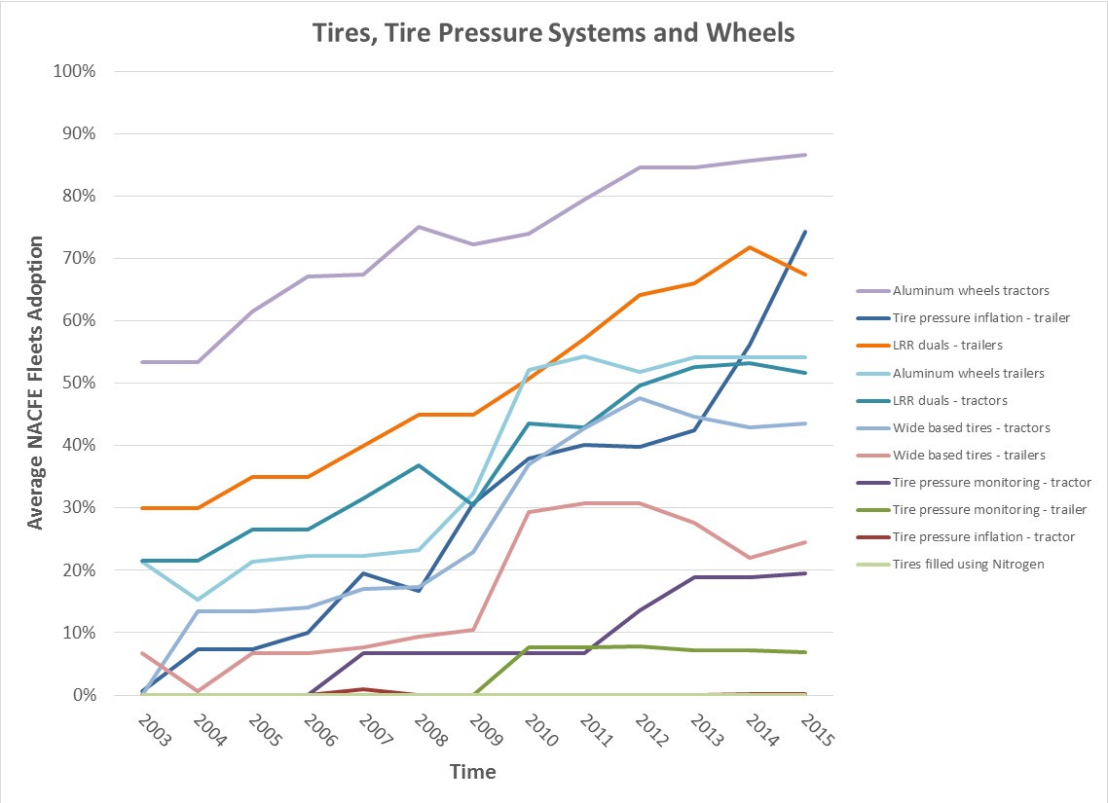

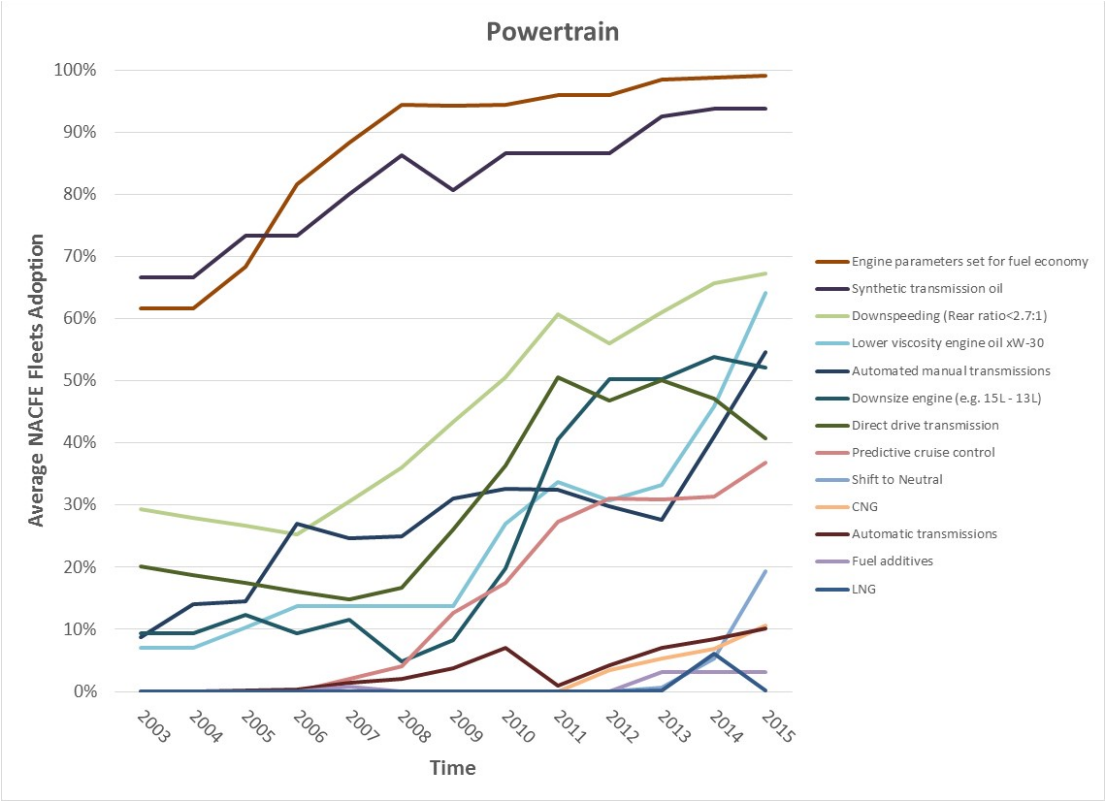

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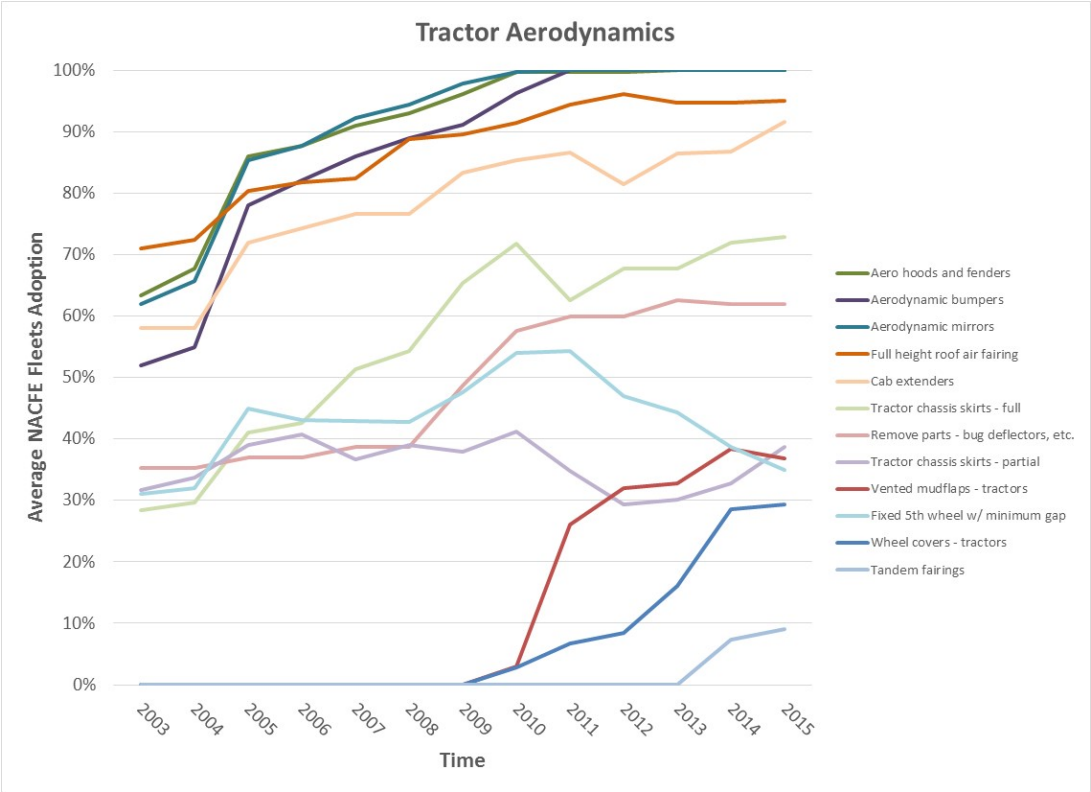

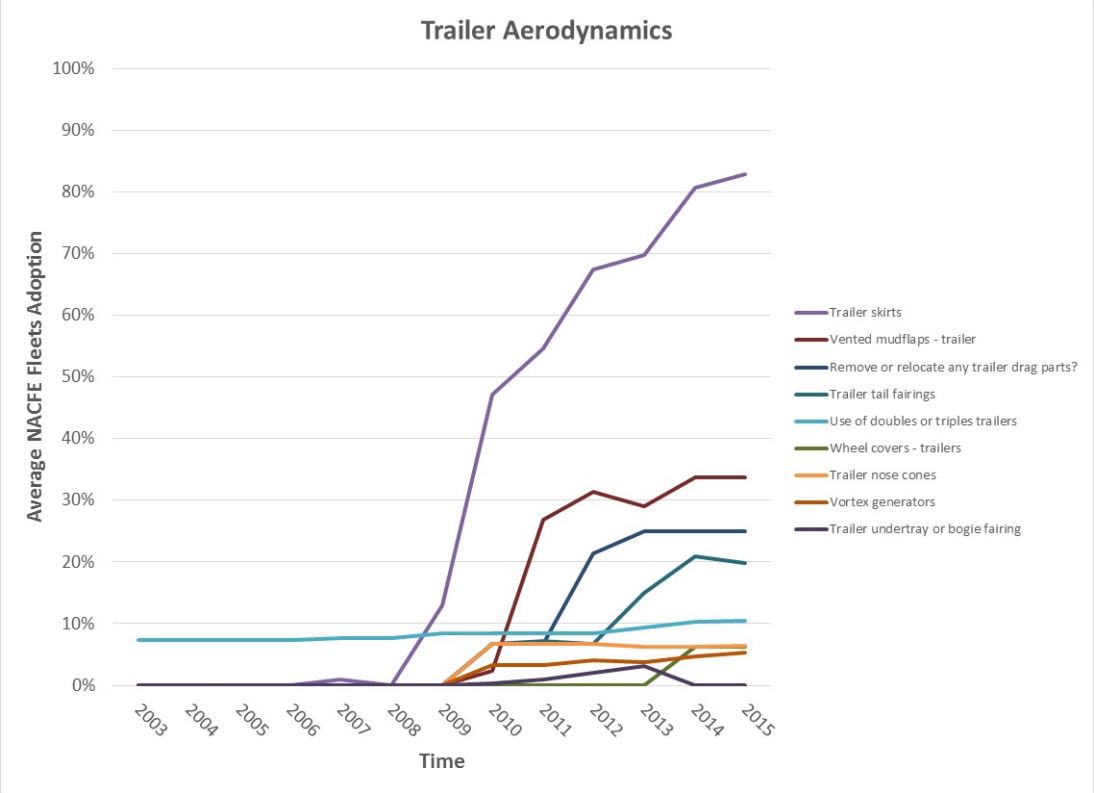

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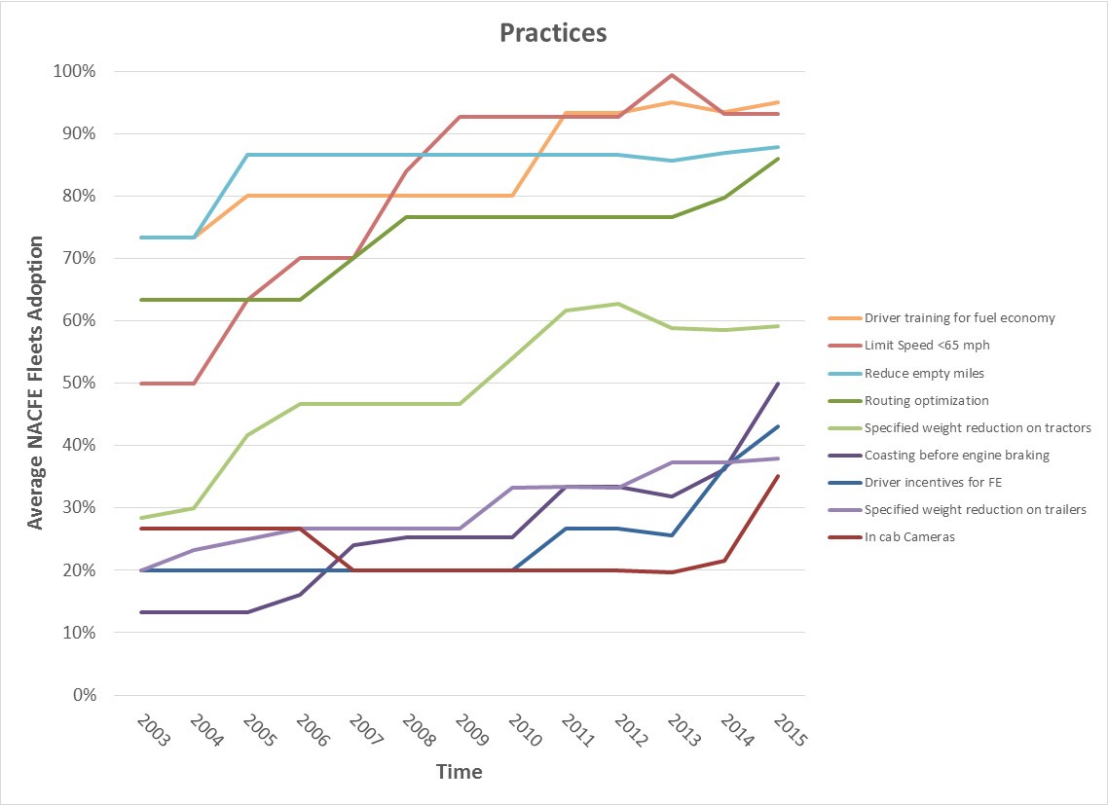

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