2014 Fleet Fuel Efficiency Benchmark Study

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

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Executive Summary

This report compares the results of a deep-dive investigation with 10 major North American fleets concerning their adoption of various products and practices for improving fuel efficiency. It identifies benchmark competencies of the companies in many different subject areas. This in-depth study is the second 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). Last year's study included 10 fleets. This year one fleet chose to no longer participate, but its data remains for years 2003 through 2012. Additionally, a new fleet's data is included: Paper Transport. This information could prove invaluable in your efforts to improve the fuel economy in your company's fleet or in developing and delivering products for the marketplace.

The scope of the work included Class 8 day cab and sleeper tractors and trailers in regional and long haul applications. Fleets in the 2014 study included CR England, Challenger Motor Freight, Con-way Truckload, Frito Lay, Paper Transport, Ryder, Schneider, Werner, Bison Transport and United Parcel Service. The primary goal was to study the level of adoption of 66 technologies and practices and the results they drove in each organization. This year, there have been some changes to the technologies analyzed. We've added CNG, LNG, 2 speed fan clutches, clutched water pumps, diesel fired heaters, automatic engine start/stop systems, and AC power ports. These were available technologies, not prototypes, validation test units or pre-production units. This study focused on what was actually purchased and implemented for a fleet's trucks and trailers. At times, the fleets were asked if they had retrofitted any of these devices on their equipment, but this was done for context, and is not included in the data.

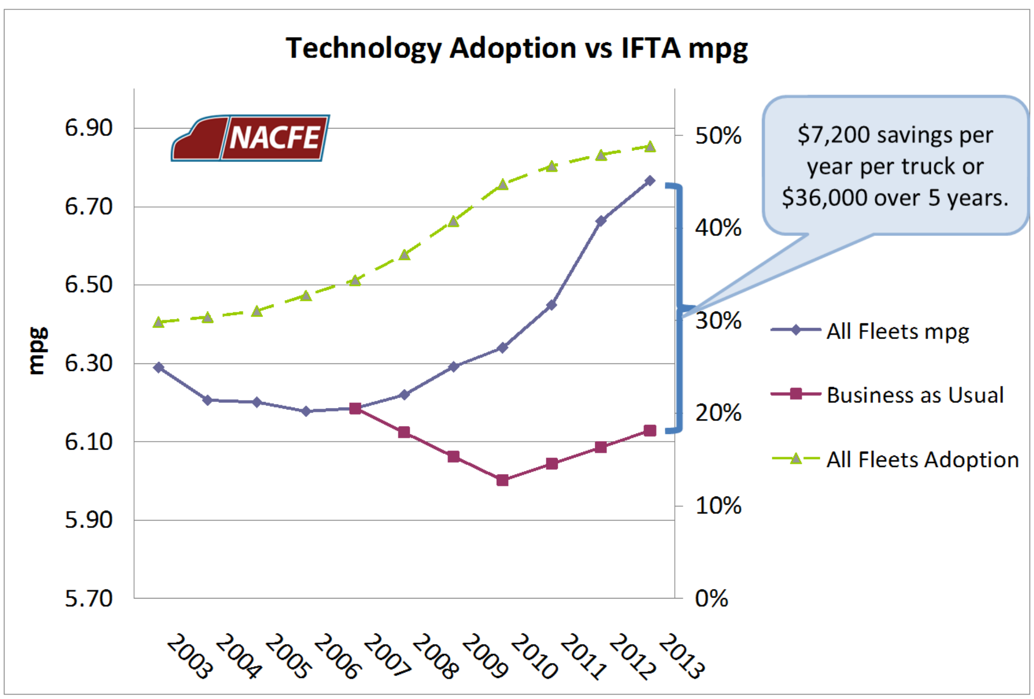


Figure 1: Adoption and Fuel Mileage

The primary finding is that the fleets studied are increasing their rate of adoption of these technologies and they are delivering improved fuel consumption. The average purchased adoption rate of these products increased from 31% to 50% over the period of 2003 through 2013, and the average fuel economy performance of the trucks improved 0.64 mpg (Figure 1). A business as usual line, predicting the combined impact of 2002, 2007 and 2010 emissions, the introduction of Selective Catalytic Reduction (SCR) as well as an assumption of very limited adoption of the technologies and practices was created for comparison to the actual real-world fuel consumption. This fuel savings in 2013 amounts to $7,200 per year per truck and is up from the 2011 report of the original eight fleets of $4,400 per year. The following report includes an addendum of the details as of the end of 2013 and is followed by the full 2013 report.

Introduction

Overview

The North American Council for Freight Efficiency (NACFE) is a nonprofit organization dedicated to doubling the freight efficiency of North American goods movement. NACFE operates in order to provide an independent, unbiased research organization for the transformation of the transportation industry. NACFE was created to bring solutions to the freight industry to radically increase fuel efficiency. Success for NACFE includes providing a place for significant sharing of proven products and practices and identifies those that are not promoting the efficient movement of goods. Success will be measured in the accelerated adoption of technologies and practices that promote freight efficiency (Figure 2). This study will highlight the success achieved by some of the more innovative fleets in North America, giving them an opportunity to share this information to encourage quicker adoption rates. Information concerning NACFE's actions can be found at www.nacfe.org.

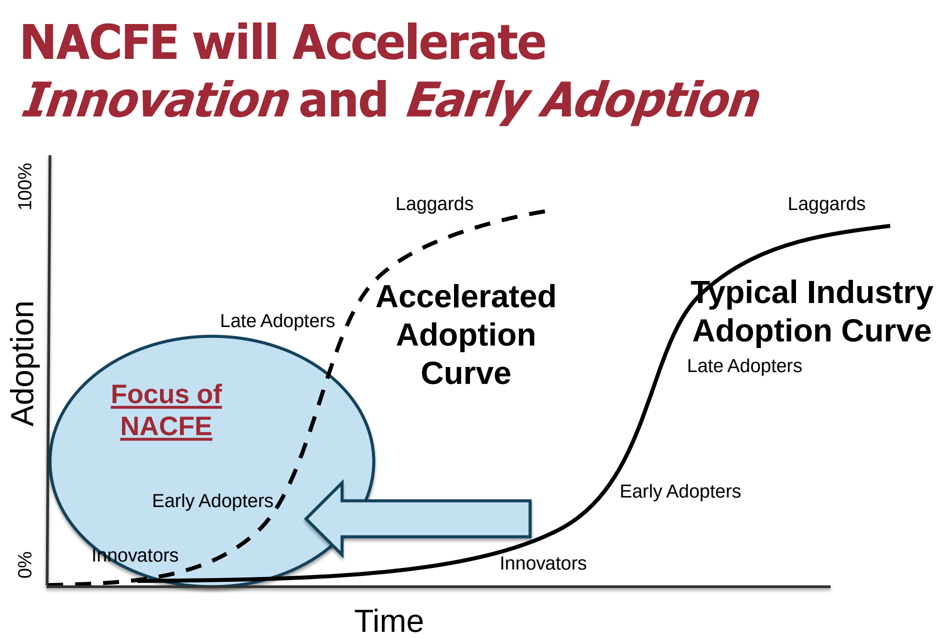


Figure 2: Accelerated Adoption Strategy

Early in 2013, NACFE entered into an alliance with the Carbon War Room (www.carbonwarroom.com) and recognizing the opportunity to accelerate the sector's fuel efficiency, NACFE and CWR launched Trucking Efficiency. Trucking Efficiency collaborates with industry experts to address the barriers to large-scale deployment of fuel-efficiency technologies and completes Technology Overviews and Confidence Reports on promising available technologies, holds workshops to openly debate their findings and recommendations and will launch an online information hub in late 2014, www.truckingefficiency.org.

Background

Fuel costs faced by the tractor-trailer industry have been swiftly and steadily rising over the past decade (Figure 3). By 2012, fuel costs had reached $0.641 per mile, as reported by the American Transportation Research Institute, surpassing even the costs for the driver (wages plus benefits) (ATRI, 2013). These costs have driven all fleets to include fuel efficiency in their new equipment specifications and operational strategies, but many do not know where to start.

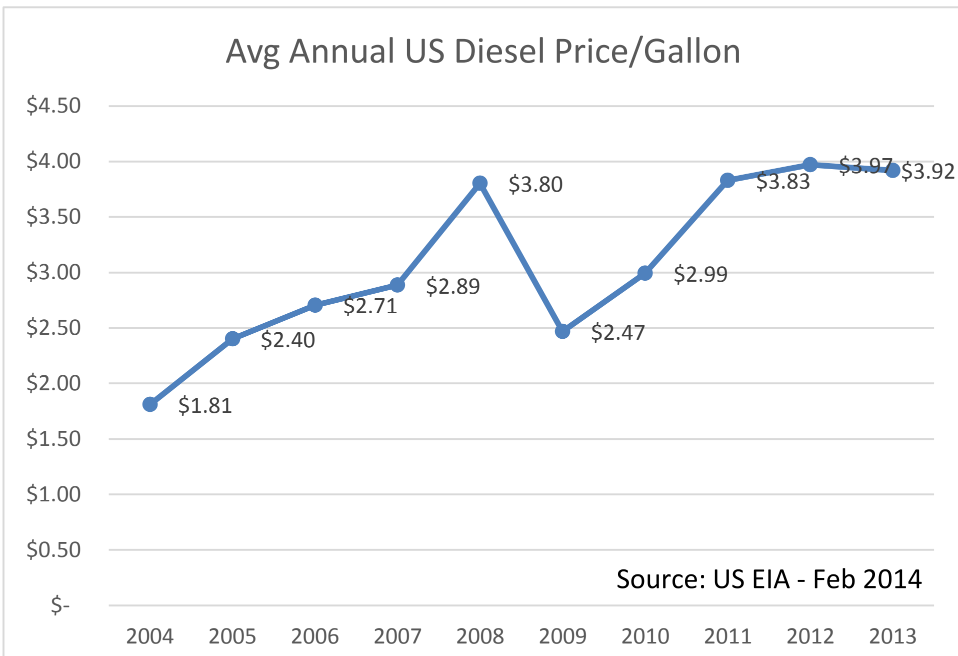


Figure 3: US Annual Diesel Fuel Prices

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

A compounding issue is the vast diversity of needs in the industry. These needs are driven by multiple, and sometimes seemingly, incompatible demands. The equipment must operate in differing duty cycles, driven by variations in operating locations (urban, rural, or a combination), geographies (mountainous/flat, hot/cold, etc.), access to capital and strategy for risk and even the business model of the fleet itself (lease vs buy equipment, use company drivers or independent contractors, in-house or contracted maintenance). These factors combine to create a significant challenge for end users to determine what technologies to pursue and which companies to consider purchasing from.

To better understand the history of adoption, NACFE, in 2010, created a best practices sharing methodology to document and learn from these early adopting fleets in order to provide an early roadmap for the industry on technologies to improve the efficiency of Class 8 tractor trailers. By the third annual fleet fuel study completed, in mid-2014, data has been accumulated on the purchasing habits of 11 fleets, operating more than 41,000 tractors and nearly 130,000 trailers. Information gathered and shared include the percent of each year's purchases that included 66 currently available technologies for lowering fuel consumption and the overall fuel efficiency of their fleets (Figure 4). With 66 technologies, 11 fleets and 11 years of data, this process provides nearly 8,500 data points of purchasing behavior on new features with these end users.

Figure 4: Fuel Efficiency Technologies

This 2014 Addendum includes updated charts and figures for data through 2013. The full 2013 report is contained within this document and begins on page 18 and includes:

- Study Design and Methodology including questions needing answers and equations for key metrics.
- Interesting Adoption Accounts
- Best Practices in Fuel Management
- Other items not duplicated in this Addendum.

Findings

Key findings from the study include:

- 119,700 miles per truck in 2013, up from 109,306 in 2012
- 3.1 trailers for every tractor
- Average age of tractors was 3.1 years and 6.0 years for trailers
- 15% of the tractors are pulling refrigerated trailers
- 11 years of adoption experiences for 66 technologies
- The average mpg of all tractors in the study was 6.77 up 8% since the start of the study in 2010.

Armed with this powerful data, much can be learned about the past and inferred to help forecast the future of these features to support a significant improvement in tractor trailer fuel efficiency. The opportunity is enormous as there are about 1.5 million tractor trailers 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. A subset of the findings is now shared here. Included are sections on fleet adoption diversity, technology adoption curves, fuel saved compared to tech adoption and consistency of adoption.

Fleet Adoption Diversity

As is in nearly all consumed products, be it business to consumer or business to business, end users tend to fall into different categories when new offerings become available. Some adopt early while some wait for others to experience the benefits and potential risks of being on the leading edge of new technologies. The 11 fleets in this study are no different (Figure 5). Fleets B, D and J can be considered early adopters, who have continued to expand their adoption, while E, I and K although later adopters have closed the gap to their more innovative counterparts. This may imply that as the fuel costs continue to rise, some end users are more aggressively benchmarking and in some cases moving to use these new products earlier in the overall adoption process of a given product.

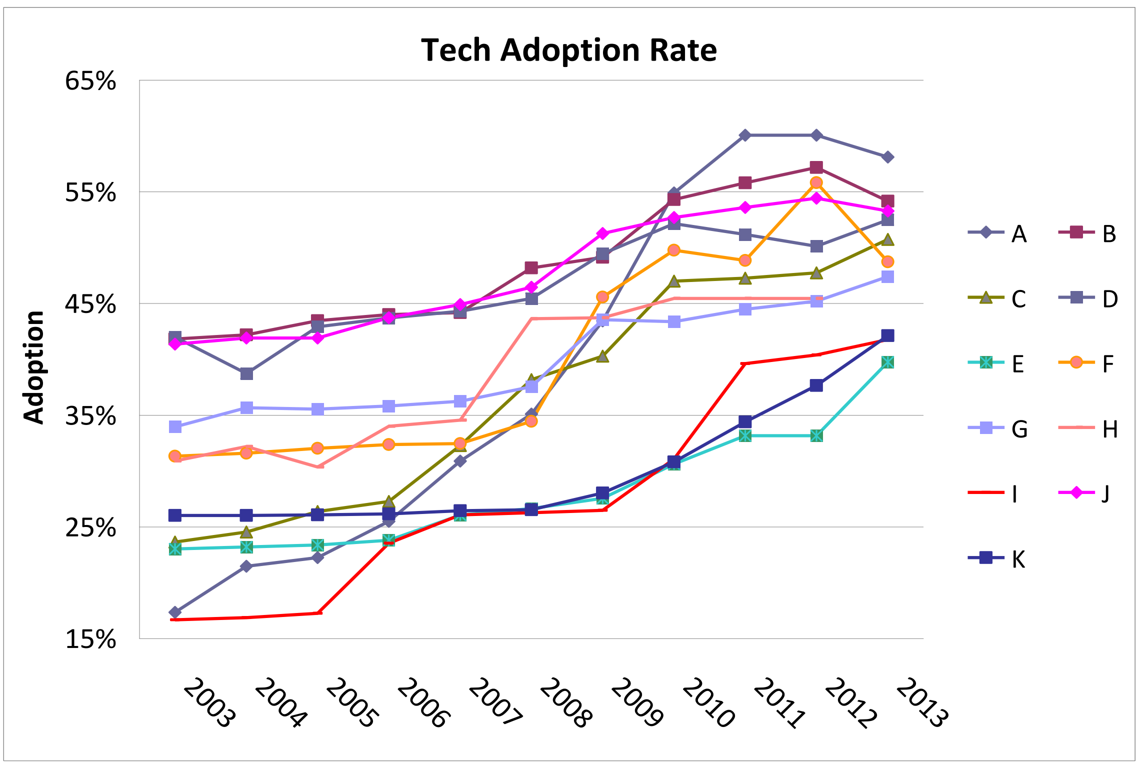


Figure 5: Fleet's Adoption

Technology Adoption Curves

Given the data provided, 66 adoption curves were created for these recognized potential fuel saving devices currently available on today's North American tractor trailers. It is important to keep in mind that these charts show only the adoption practice of these 11 fleets, which represent about 2.5% of the overall trucks in North America. It also recognizes each fleet as a single decision in the adoption calculation rather than by total volume of tractors or trailers procured. 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 purchase of trailer skirts to over 70% is the quickest current rate of all technologies.

The 66 technologies were grouped into six categories: anti-idling, chassis, practices, tires/wheels, tractor aerodynamics and trailer aerodynamics. Technology adoption by category is displayed first, followed by charts showing each technology and finally, the data in a table (Figures 6, 7, 8, 9, 10, 11, 12 and Table 1).

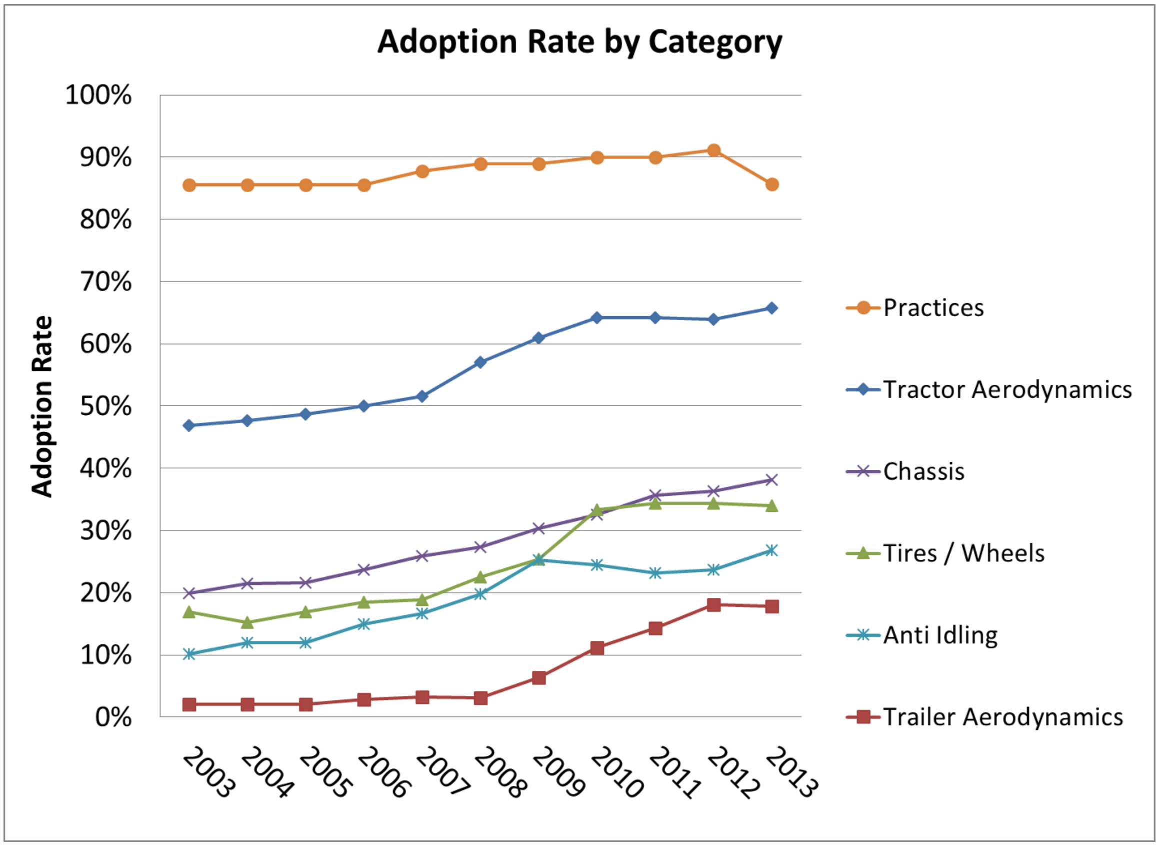


Figure 6: Adoption by Technology Category

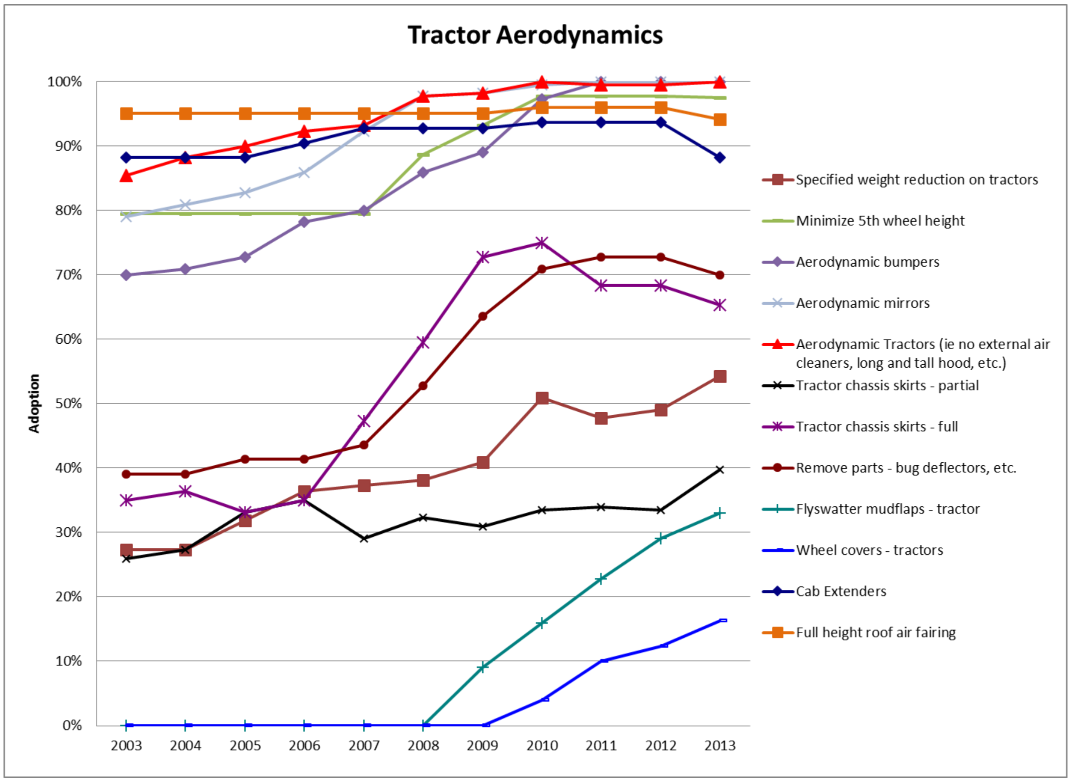


Figure 7: Adoption of Tractor Aerodynamics Technologies

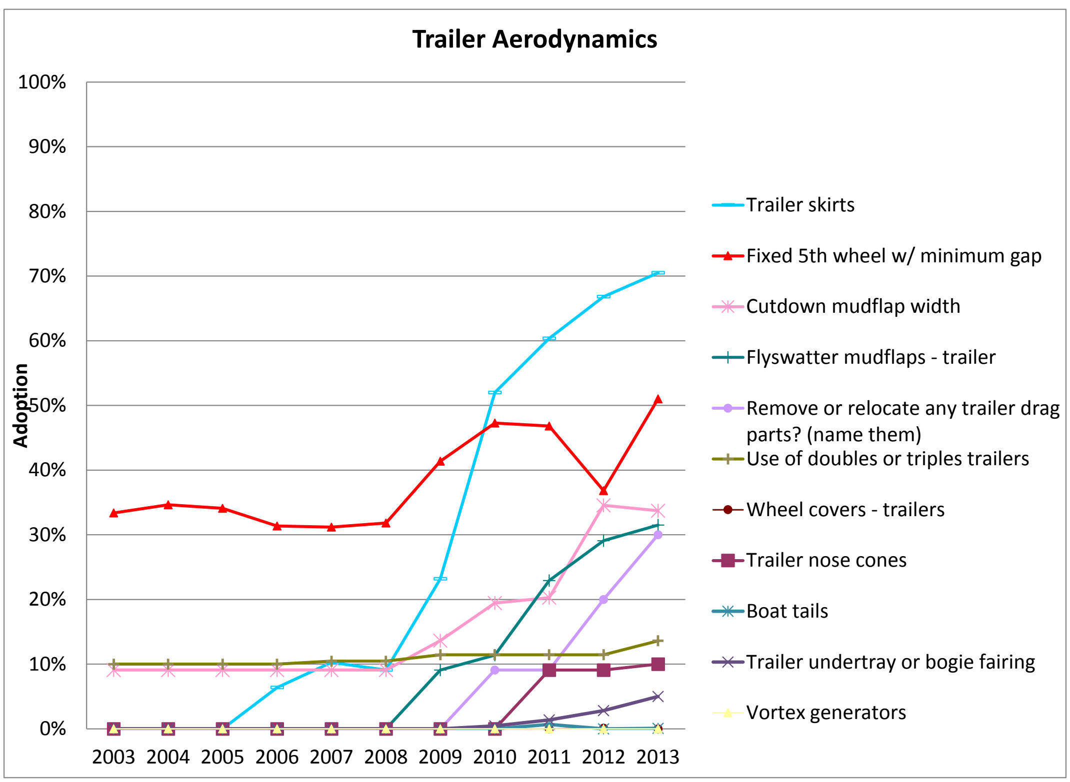


Figure 8: Adoption of Trailer Aerodynamics Technologies

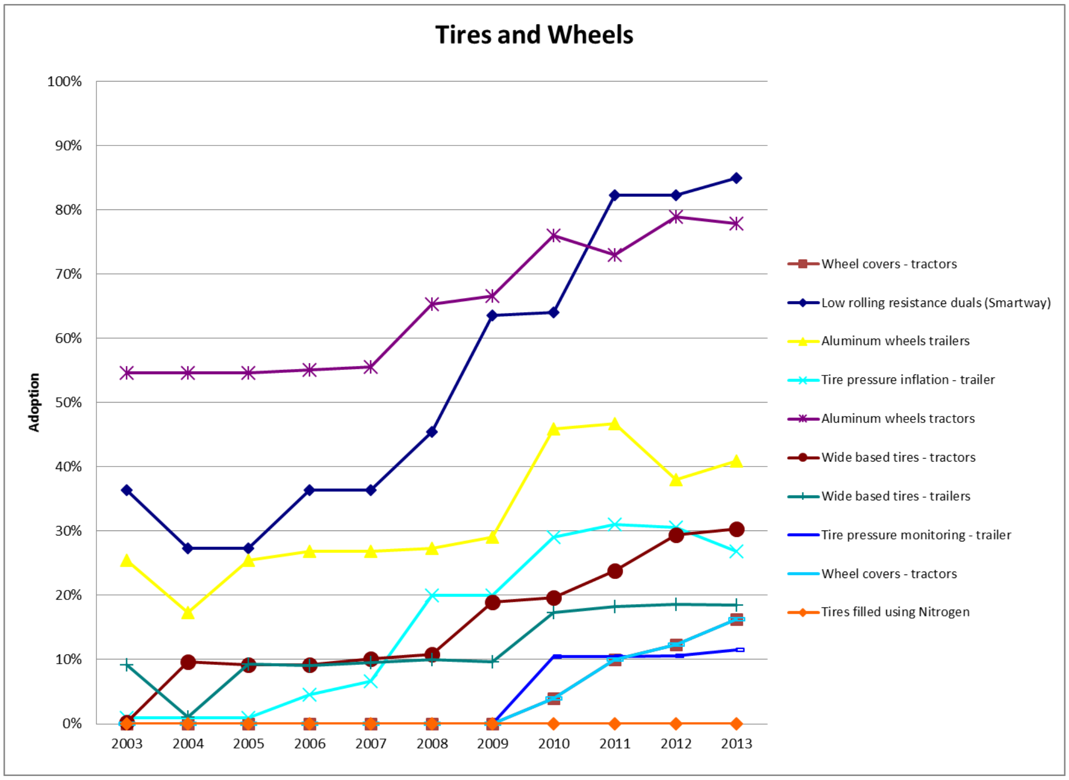


Figure 9: Adoption of Tires and Wheels Technologies

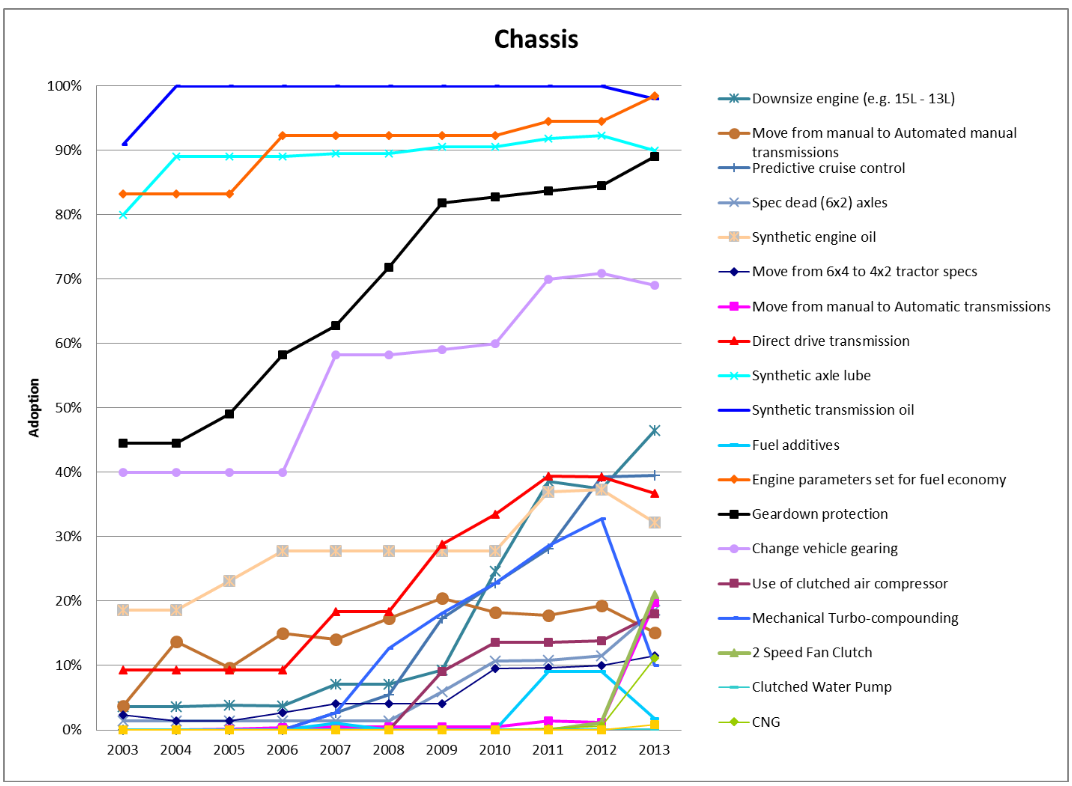


Figure 10: Adoption of Chassis Technologies

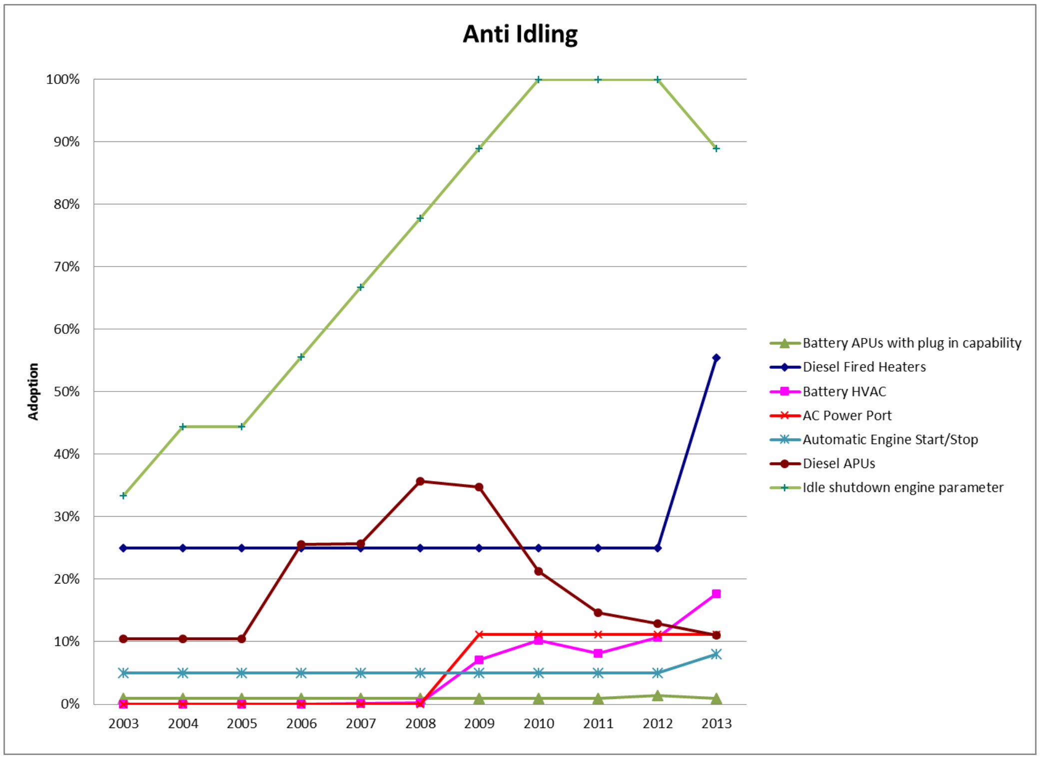


Figure 11: Adoption of Anti Idle Technologies

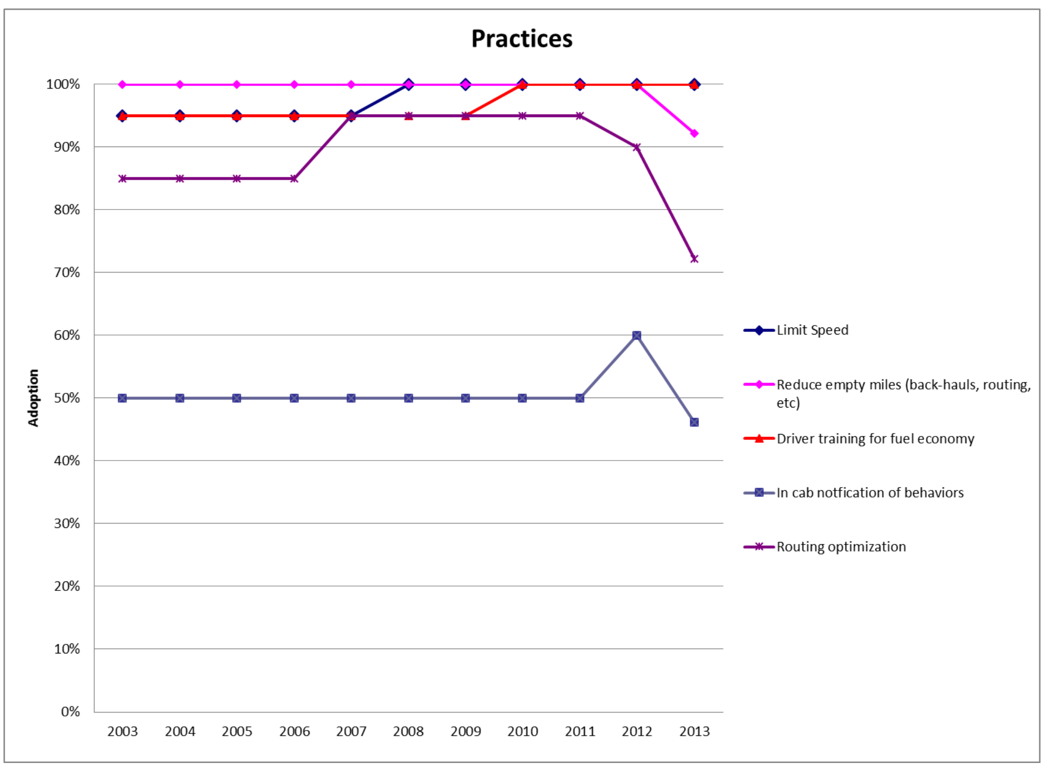


Figure 12: Adoption of Practices

% with the following technologies	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Aerodynamics											
Aerodynamic Tractors (ie no external air cleaners, long and tall hood, etc.)	86%	89%	91%	94%	95%	100%	100%	100%	100%	100%	100%
Tractor chassis skirts - partial	21%	22%	29%	31%	24%	28%	26%	27%	27%	27%	40%
Tractor chassis skirts - full	31%	32%	29%	31%	44%	58%	72%	73%	65%	65%	65%
Aerodynamic bumpers	69%	70%	72%	78%	80%	87%	90%	97%	100%	100%	100%
Aerodynamic mirrors	79%	81%	83%	87%	94%	100%	100%	100%	100%	100%	100%
Remove parts - fender mirrors?	14%	14%	14%	10%	10%	30%	30%	30%	25%	25%	25%
Remove parts - bug deflectors, etc.	35%	35%	38%	38%	40%	50%	62%	68%	70%	70%	70%
Full height roof air fairing	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%	94%
Cab Extenders	89%	89%	89%	92%	94%	94%	94%	94%	94%	94%	88%
Fixed 5th wheel w/ minimum gap	37%	38%	38%	35%	34%	35%	43%	50%	49%	38%	51%
Minimize 5th wheel height	80%	80%	80%	80%	80%	90%	95%	100%	100%	100%	98%
Flyswatter mudflaps - tractor	0%	0%	0%	0%	0%	0%	10%	15%	20%	25%	33%
Wheel covers - tractors	0%	0%	0%	0%	0%	0%	0%	4%	10%	10%	15%
Specified weight reduction on tractors	20%	20%	25%	30%	31%	32%	35%	46%	43%	44%	54%
Wheel covers - trailers	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Flyswatter mudflaps - trailer	0%	0%	0%	0%	0%	0%	10%	10%	20%	25%	32%
Trailer skirts	0%	0%	0%	7%	11%	10%	26%	57%	65%	70%	71%
Trailer undertray or bogie fairing	0%	0%	0%	0%	0%	0%	0%	1%	2%	3%	5%
Trailer nose cones	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%
Vortex generators	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Boat tails	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%
Cutdown mudflap width	10%	10%	10%	10%	10%	10%	15%	21%	22%	38%	34%
Remove or relocate any trailer drag parts? (name them)	0%	0%	0%	0%	0%	0%	0%	10%	10%	22%	30%
Use of doubles or triples trailers	11%	11%	11%	11%	12%	12%	13%	13%	13%	13%	14%
Tires / Rolling Resistance											
Tire pressure monitoring - trailer	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%	12%
Tire pressure inflation - trailer	1%	1%	1%	5%	7%	22%	22%	32%	33%	32%	27%
Specified weight reduction on trailers	40%	40%	40%	40%	40%	40%	40%	60%	50%	50%	60%
Low rolling resistance duals (Smartway)	30%	20%	20%	30%	30%	40%	60%	61%	81%	81%	85%
Wide based tires - tractors	0%	11%	10%	10%	11%	11%	19%	19%	22%	27%	30%
Wide based tires - trailers	10%	1%	10%	10%	11%	11%	11%	19%	20%	20%	19%
Aluminum wheels tractors	60%	60%	60%	61%	61%	71%	71%	82%	77%	82%	78%
Aluminum wheels trailers	28%	19%	28%	30%	30%	30%	32%	51%	51%	42%	41%
Tire pressure monitoring - tractor	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
Tires filled using Nitrogen	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% with the following technologies	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Chassis											
Move from 6x4 to 4x2 tractor specs	1%	0%	0%	2%	3%	3%	3%	9%	9%	9%	12%
Spec dead (6x2) axles	0%	0%	0%	0%	0%	0%	5%	10%	10%	11%	14%
Move from manual to Automated manual transmissions	4%	15%	11%	16%	15%	19%	22%	20%	19%	20%	15%
Move from manual to Automatic transmissions	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	20%
Downsize engine (e.g. 15L - 13L)	4%	4%	4%	4%	8%	8%	10%	27%	40%	38%	47%
Direct drive transmission	10%	10%	10%	10%	20%	20%	30%	35%	41%	39%	37%
Synthetic axle lube	88%	98%	98%	98%	98%	98%	98%	98%	98%	98%	90%
Synthetic transmission oil	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%
Synthetic engine oil	20%	20%	25%	30%	30%	30%	30%	30%	40%	40%	32%
Fuel additives	0%	0%	0%	0%	1%	0%	0%	0%	10%	10%	2%
Engine parameters set for fuel economy	84%	84%	84%	94%	94%	94%	94%	94%	94%	94%	99%
Geardown protection	45%	45%	50%	60%	65%	75%	85%	85%	85%	85%	80%
Predictive cruise control	0%	0%	0%	0%	3%	6%	19%	25%	31%	43%	49%
Change vehicle gearing	40%	40%	40%	40%	60%	60%	60%	60%	70%	70%	69%
Use of clutched air compressor	0%	0%	0%	0%	0%	0%	10%	15%	15%	15%	18%
Mechanical Turbo-compounding	0%	0%	0%	0%	3%	14%	20%	25%	32%	36%	10%
CNG	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%
LNG	0%	0%	0%	0%	0%	0%	10%	20%	20%	20%	11%
Anti Idling											
Electronic Engine Controls	30%	40%	40%	50%	60%	70%	86%	90%	90%	92%	85%
Diesel APUs	10%	10%	10%	25%	25%	35%	34%	21%	14%	12%	11%
Battery HVAC	0%	0%	0%	0%	0%	0%	7%	10%	8%	11%	16%
Battery APUs with plug in capability	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%
Automatic Start/Stop	0%	0%	0%	0%	0%	0%	10%	10%	10%	10%	15%
Practices											
Limit Speed	85%	85%	85%	85%	85%	90%	90%	90%	90%	90%	90%
Reduce empty miles (back-hauls, routing, etc)	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	83%
Driver training for fuel economy	85%	85%	85%	85%	85%	85%	85%	90%	90%	90%	90%
In cab notfication of behaviors	50%	50%	50%	50%	50%	50%	50%	50%	50%	60%	42%
Routing optimization	75%	75%	75%	75%	85%	85%	85%	85%	85%	80%	65%

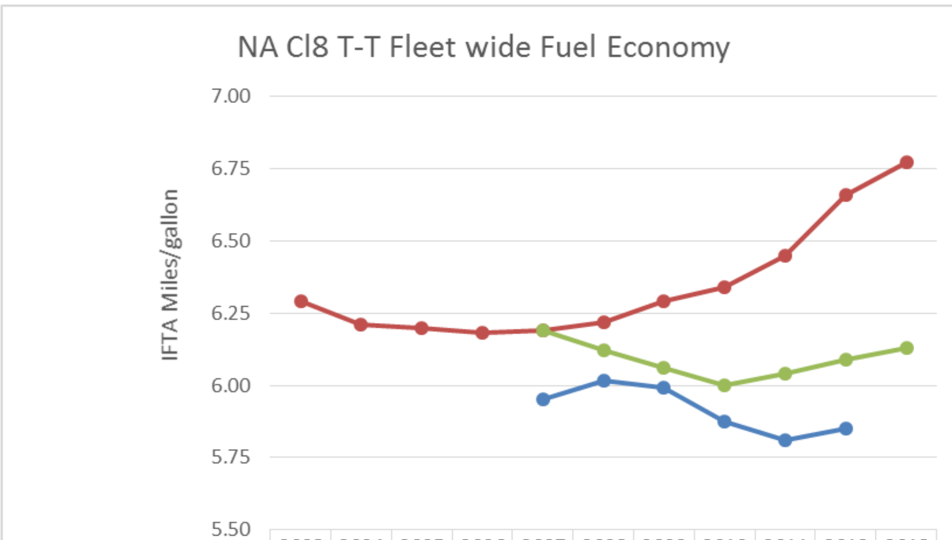
Table 1: Adoption of All Technologies

<u>Fuel Saved Compared to Tech Adoption</u>

The previous pages showed the uptake over time of these various technologies, this raises many additional questions. What impact do these technologies have on the fuel efficiency of the trucks in the fleet? What is the payback on investment of each of these technologies? And others. The fuel efficiency of these fleets of tractors and trailers is shown below and is shaped in a bit of a bathtub type curve. The mpg shown is for all trucks in the fleet in that year, so it includes tractors and trailers procured in the years prior to each year on the plot. It is expected that the fuel efficiency curve should lag by a few years the adoption curve as it represents the features purchased on new equipment bought in that year.

In the first third of this time period under study, 2003 to 2006, the impact of the introduction and purchase of EPA04 and EPA07 emissions level engines caused an overall decrease in fuel efficiency. In the second third, 2007 to 2010, procurement of new fuel economy technologies grew and for these fleets began to stabilize and overcome the degrading effect of the new emissions engines. Finally, in the years 2011 to 2013, the fuel efficiency of this fleet improved from 6.34 to 6.77 mpg, a nearly 7% improvement.

The study team also created a business as usual prediction, one that compares these fleets with a baseline fleet who only procured a few of the highest adopted technologies. The NACFE business as usual predictions maps well against data reported by the U.S. Department of Transportation's Federal Highway Administration (Figure 13) for the approximately 1.5m over the road tractor trailers operating in the United States.



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
US DOT FHA					5.95	6.02	5.99	5.87	5.81	5.85	
NACFE Study Data	6.29	6.21	6.20	6.18	6.19	6.22	6.29	6.34	6.45	6.66	6.77
NACFE BAU					6.19	6.12	6.06	6.00	6.04	6.09	6.13

Figure 13: Fleet-wide Fuel Economy

The studied fleets are saving over $7,200 per truck per year in fuel compared to a fleet that is not buying these technologies (Figure 14). This amounts to around $36,000 over a five year first user ownership period. 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 3-year payback for these technologies. This payback will improve in the future with higher adoption leading to lower prices.

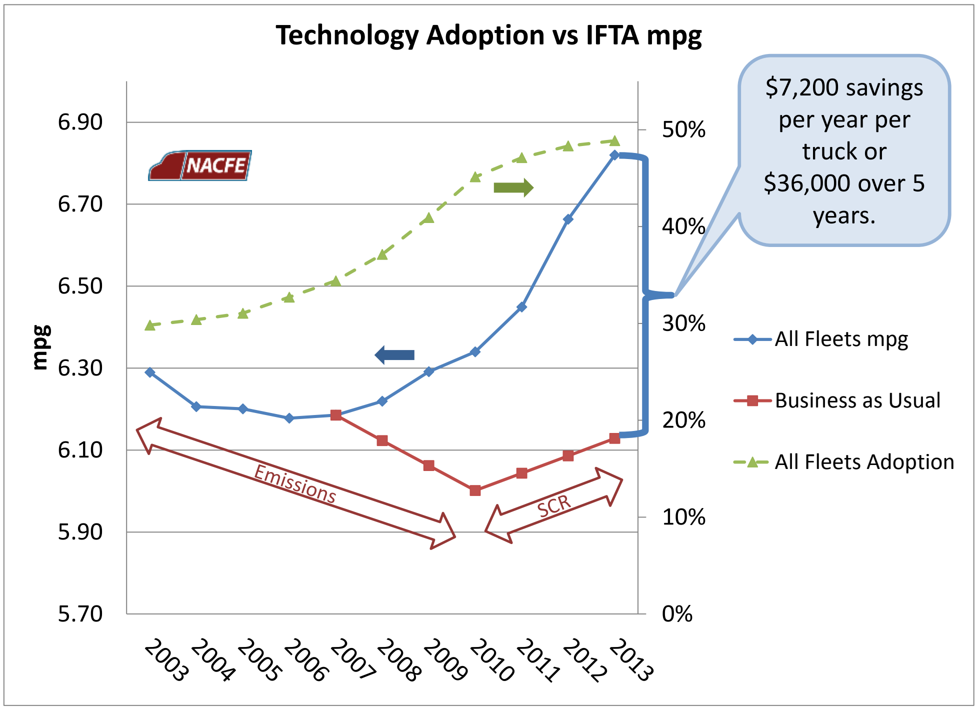


Figure 14: Fleet-wide Fuel Consumption

<u>Fleet Consistency of Adoption</u>

Finally, as in previous years, the consistency of adoption by the various fleets was evaluated. Here each of the 66 technology decisions by each of the 11 fleets is compared using a categorization methodology showing whether the technology is being purchased by the fleet, how quickly it increased to 100% of all purchases or even if a fleet decided to stop buying them. Figure 15, shows the technologies stacked by the most popular.

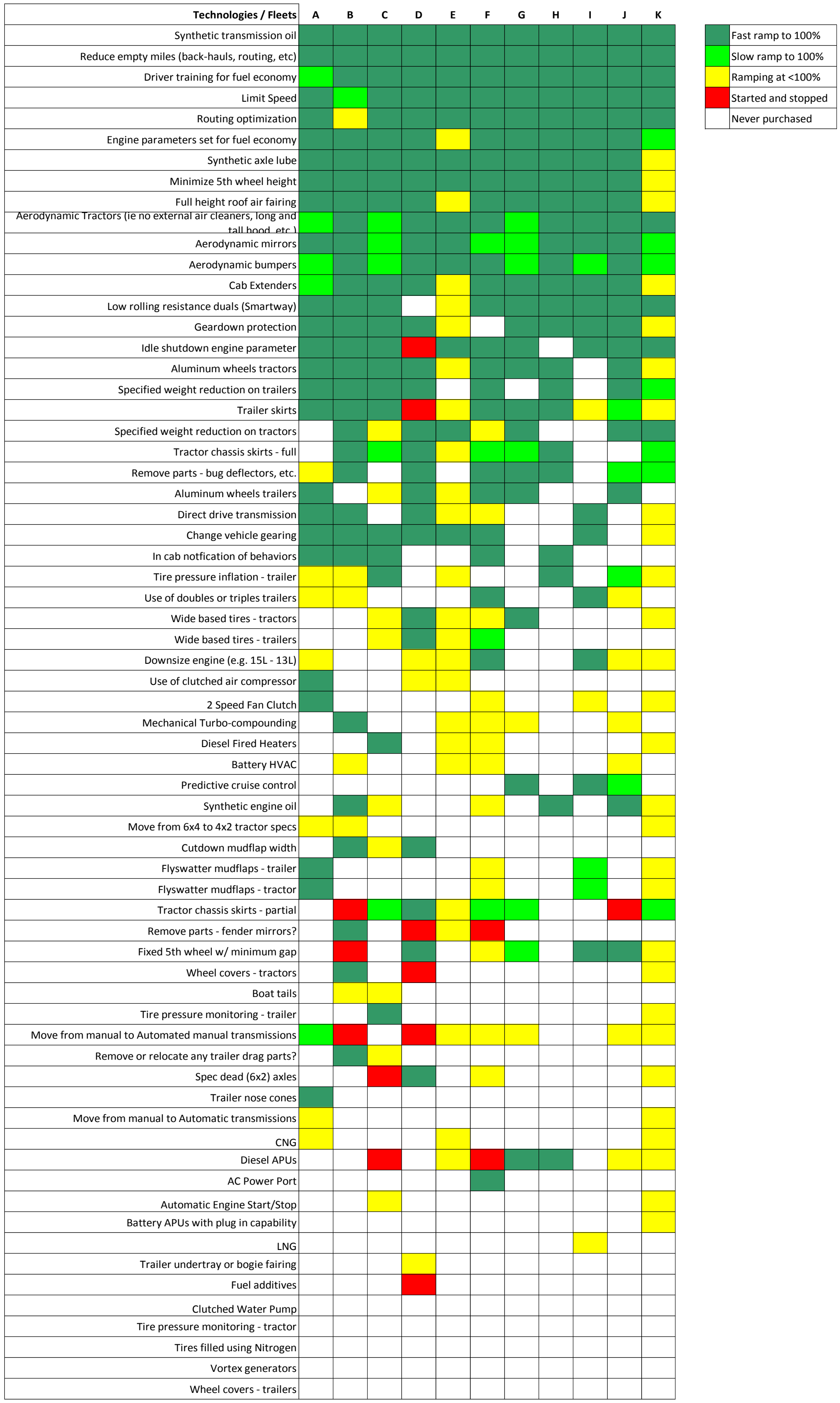


Figure 15: Consistency of Adoption

Other fleets now have a roadmap for technologies that are determined to have a positive impact on lowering fuel expenses. A simple fleet investigation method could be:

1. Look at the top third of the table for technologies most commonly adopted by the 11 fleets in this study and consider specifying them on your next tractor and trailer. Ask yourself very specifically, why you are not buying these technologies?
2. Investigate the bottom third technologies. In some cases, these technologies may be new and their true adoption down the road is not reflected here.
3. Explore the middle third. These technologies may be specific to a fleet's duty cycle or business model and therefore, have less uniformity of adoption be the fleets. These technologies will also offer good options for fleets to consider purchasing.

Conclusion

New technologies are becoming much more available to improve tractor trailer efficiency, but this poses both opportunities and challenges. Each fleet must determine the best set of solutions for its individual needs, and this study data can assist the fleet in doing so. Doing nothing and losing ground in fuel cost competitiveness to other fleets is not an option. NACFE along with the CWR are continuing its series of Confidence Reports on some of the more promising technologies. Reports have been completed on;

- Tire Pressure Systems – Tire Pressure Monitoring and Automatic Tire Inflation
- 6x2 Axle Configurations
- Idle Reduction Solutions – Diesel APUs, Battery HVAC, Auto Start/Stop, Truck Stop Electrification, Diesel Fired Heaters with Driver Training and Incentives and other complementary solutions
- Automated Transmissions – Automated Manuals and Automatics

These can be found soon at www.truckingefficiency.org the new information platform of the Trucking Efficiency Operation, the combined effort of the Carbon War Room and NACFE.

Also, following is the full 2013 report. It has been included to provide details on the study methodology and sections on interesting technology adoption accounts and best practices for fuel efficiency programs.

Thanks for your interest in this work.

References

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American Transportation Research Institute, "Operational Costs of Trucking Report", September 4, 2013.

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Executive Summary

This report compares the results of a deep-dive investigation with ten major North American fleets concerning their adoption of various products and practices for improving fuel efficiency. It identifies benchmark competencies of the companies in many different subject areas. This in-depth study is the first annual update of the 2011 inaugural study that has been called "The most comprehensive study of Class 8 fuel efficiency adoption ever conducted". That original study included eight fleets and each return with updated information and is now joined by two more; Bison Transport and UPS. This information could prove invaluable in your own efforts to improve on fuel economy in your company's fleet or in developing and delivering products for the marketplace.

The scope of the work included Class 8 day cab and sleeper tractors and trailers in regional and long haul applications. Fleets in the 2011 study included CR England, Challenger Motor Freight, Con-way Truckload, Frito Lay, Gordon Trucking, Ryder, Schneider and Werner. This group is now joined by Bison Transport and United Parcel Service bringing the total number of tractors operated by these companies to over 90,000 tractors and over 200,000 trailers. The primary goal was to study the level of adoption of 60 technologies and practices and the results they drove in each organization. These were available technologies, not prototypes, validation test units or pre-production. This study focused on what was actually purchased and implemented for a fleet's trucks. At times, the fleets were asked if they had retro-fitted any of these devices on their equipment, but this was done for context, and is not included in the data.

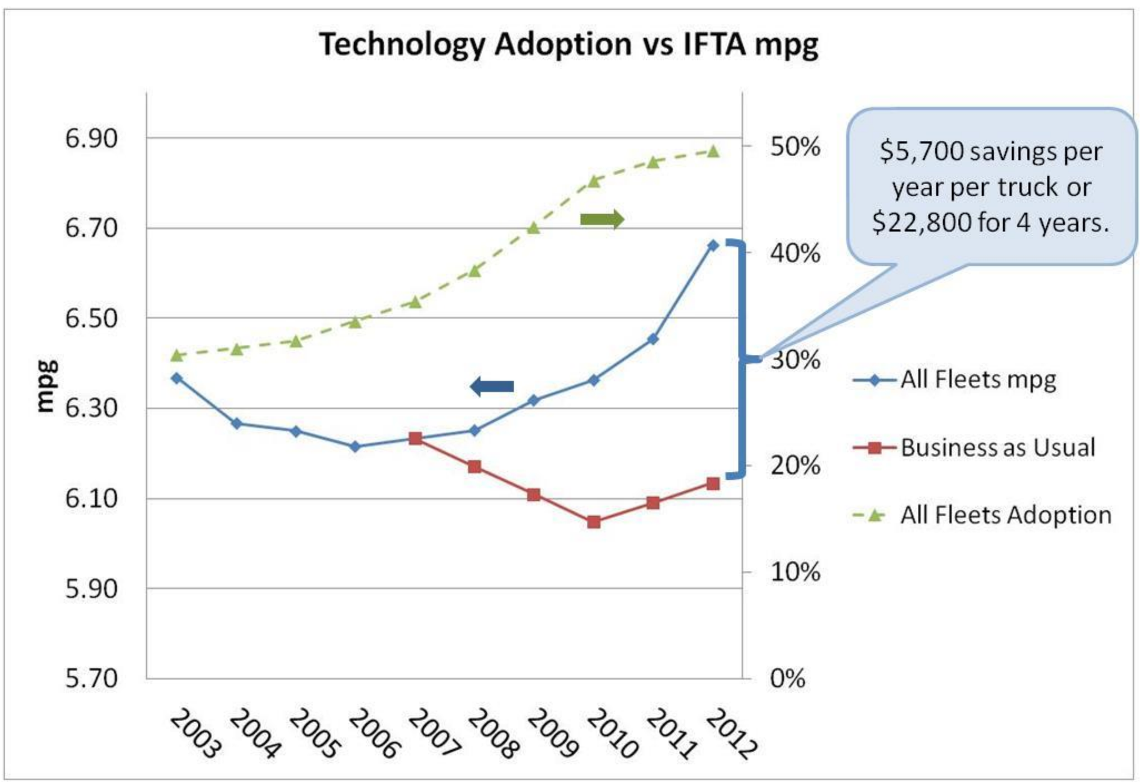

Figure 1: $5,700 per Year per Truck Savings

The primary finding is that the fleets studied are increasing their rate of adoption of these technologies and they are delivering improved fuel consumption. The average purchased adoption rate of these products increased from 31% to 50% over the period of 2003 through 2012 and the average fuel economy performance of the trucks improved 0.53 mpg (Figure 1). A business as usual line, predicting the combined impact of 2002 and 2007 emissions, the introduction of Selective Catalytic Reduction (SCR) as well as an assumption of very limited adoption of the technologies and practices was created for comparison to the actual real-world fuel consumption. These trucks averaged 109,000 miles per year and at $4 per gallon diesel fuel, this improvement equates to $5,700 fuel saved per truck per year or $22,800 over a 4 year time period. This fuel savings is up from the 2011 report of the original eight fleets of $4,400 per year. The following report will detail the adoption experience by fleet of the 60 technologies, share specific interesting technology accounts and provide benchmark practices for improving the fuel performance of a fleet's trucks.

Introduction

Overview

The North American Council for Freight Efficiency ("NACFE") is a nonprofit organization dedicated to doubling the freight efficiency of NA goods movement. The NACFE operates in order to provide an independent, unbiased research organization for the transformation of the transportation industry. The NACFE was created to bring solutions to the freight industry radically increase fuel efficiency. Success for the NACFE is that it provides a place for significant sharing of proven products and practices and identifies those that are not promoting the efficient movement of goods. Success will be measured in the accelerated adoption of technologies and practices that promote freight efficiency. This study will highlight the success achieved by some of the more innovative fleets in North America, giving them an opportunity to share this information to encourage quicker adoption rates. Information concerning the NACFE's actions can be found at www.nacfe.org.

Biggest Fleet Challenges

Fuel is one of the greatest costs of operating a fleet. At the current $4 per gallon diesel fuel cost, the fleets shared that the total cost of fuel generally surpasses their driver labor costs making fuel the highest single expense. The fleets in the study shared their challenges to put in place both practices and technologies for lowering fuel consumption. Obviously the initial purchase cost of the technology or implementation of a practice is the first challenge. The payback must be acceptable and the capital available for the increased upfront cost. The following five challenges were also identified as primary obstacles to more aggressive introduction of new technologies on commercial vehicles.

- Generally, the first mentioned is reliability. The number 1 measure of efficiency for trucks is do they run or do they not? Can they be relied on day in and day out to perform their intended functions? Any technology put on a truck simply has to work. The fleets bluntly demanded that the new trucks must be more reliable than the ones they replace.
- Another challenge is that sometimes these features conflict with other fleet requirements such as driver recruitment and retention and residual value. Residual value seemed to stand out as a large factor in determining which and how many of a new product is introduced. Many of these for-hire firms have a relatively short trade cycle and the residual value of a new technology may not have matured enough to allow adequate return on investment via the resale of the truck with the new items.
- The challenge of validating through testing can be very difficult and expensive. That's a factor to consider when these fleets have to make decisions to buy these technologies or not.
- Another challenge is the possibility of competing goals within a fleet organization itself. Some fleets were more dedicated to fuel savings than others, and there's always the question of "can we afford

it?" Most of these components cost more, and weigh more. Generally, it costs more money to have a highly fuel efficient truck.

- Finally, a major challenge for a number of the fleets in the study, particularly with a couple of fleets that have turnover plans or resale strategies in a three- to four-year time period is that if there's a three-year payback and they trade the truck in three years, they haven't gained the payback in those final years. As many of these fleets only keep their trucks for about 60 – 70% of their useful life, it can be difficult to see a return on that investment.

Primary Study Questions

Below is a list of the primary study questions that the NACFE team developed as part of the study methodology. The questions focused on which technologies were adopted, how quickly they were adopted, what kind of benefits they provided, were there adverse consequences, etc.

- What challenges exist within the fleets that hinder mpg improvement?
- Which technologies are getting the highest adoption by fleets?
- What is the fuel economy improvement of these technologies?
- Is the adoption by technology universal across the study fleets?
- What can we learn about the reason for technologies that had a start and stop? And maybe restart?
- What can we learn about the technologies that had a quick adoption?
- What best practices exist for fleets to adopt these technologies and improve mpg?
- What can we learn about 2nd or 3rd generation products adoption versus 1st generation?
- What can for-hire fleets learn from private fleets and private fleets learn from for-hire fleets with respect to fuel management.

Related Research

Other Studies

The study team reviewed other studies related to the adoption of technologies available to fleets during the identified study period, 2003 to 2012. The Northeast States Center for a Clean Air Future (NESCCAF) in their October, 2009 report "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions" identified 32 technologies and practices in order to predict a better future state for truck fuel consumption (NESCAUM). In their Appendix D, a model was created that predicted fleet adoption of various technologies for forecasting the potential improvement expected in the future. In 2008 and 2009, a National Academy of Sciences committee also studied the commercial vehicle fuel consumption reduction opportunity and in March 2010 published its work as a predecessor to the EPA and NHTSA rule making on legislation for greenhouse gas emissions (NAS). In 2008, this committee worked with suppliers and original equipment manufacturers to predict the current rate of adoption of various technologies. Finally, there are various references to the planned adoption of technologies in the rulemaking documents themselves (EPA). The truck press also offers helpful discussions of the ordering of various features available for purchase on new trucks. As the NACFE reviewed this work, the opportunity to obtain data directly from the fleets that purchase these trucks and components was believed to be highly valuable to share across these participating fleets, with other companies operating trucks and with the industry at large.

NAFCE's prior views

The NACFE had some prior views on this topic before the study was initiated. In Figure 2, a classic product adoption curve is presented, where any new product offering has innovators, early adopters, etc. all the way to the laggards of new product acceptance. In medium-duty and heavy-duty trucks, there is a belief and the history would suggest a slow ramp of new products into this market. There is a tendency to be slow to adopt technology for a number of valid reasons, identified in the box. The NACFE believes that these challenges are actionable and one of the Council's main goals is to provide the industry with credible data that proves this.

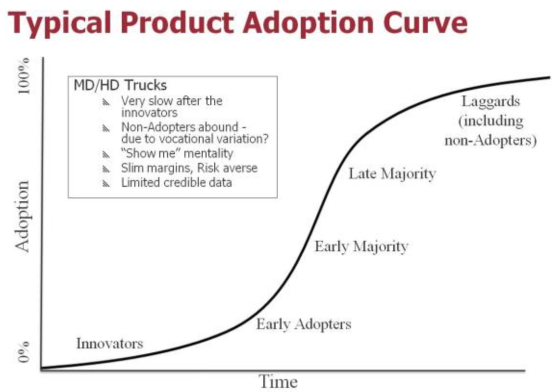

Figure 2: Typical Product Adoption Curve

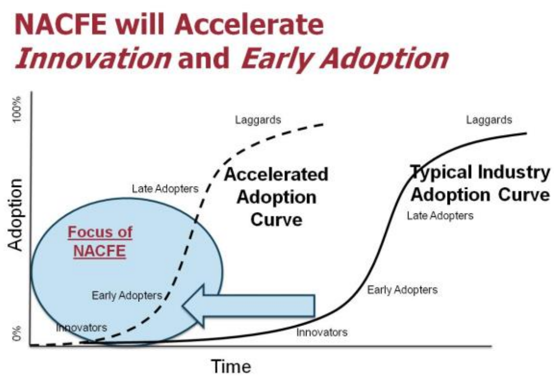

Figure 3: NACFE Mission

Figure 3 demonstrates the mission of the Council to deliver credible data, provide education and lead projects that will help accelerate the adoption of the products and practices that are truly delivering. The goal is to also share adverse consequences of the introduction of products and provide details on those that may not offer a sufficient payback. This will allow focus of the entire industry on the items most effective in providing freight efficiency improvements.

The NACFE created the graph in Figure 4, which was an assumption of various adoption curves for some features launched into the industry over the past years. For instance, integrated sleepers had a very quick adoption back in the late '90s for tractor/trailers, but some other technologies like aerodynamic tractors, automatic transmissions, etc., seemed to be on a pace which would take a decade or two to be fully adopted. This study provides some real world, fleet provided data for 60 technologies and practices that detail these adoption curves.

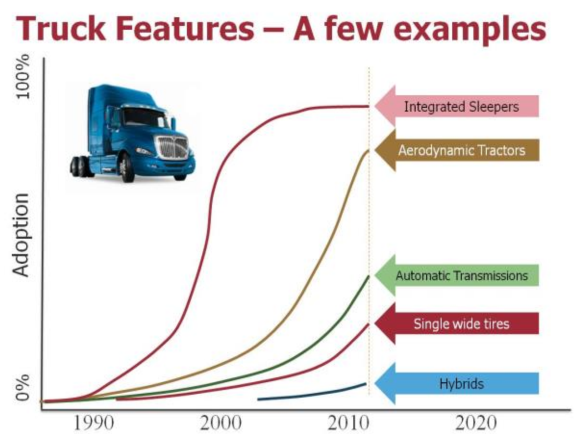

Figure 4: Truck Adoption

Study Design and Methodology

Figure 5: Study Activities

As stated earlier, the goal of this Fleet Fuel Efficiency Study was to understand the past adoption of technologies to improve fuel efficiency in order to learn from these experiences and to share the experiences of the various technologies, their value to fleets and the consequences of their introduction and to share best practices in fleet fuel expense management. The Technical Advisory Committee of the NACFE comprised only of fleets and engineering / testing companies created the strategy for the study and identified a study team to execute it. Figure 5 shows the general activities completed during the study period.

The scope of the project was defined as:

- Over the Road Tractors and 53' Trailers.
- Include 8 to 10 innovative fleets with significant scale.
- Private and For-Hire carriers in dry van or refrigerated goods movement.
- Evaluate the adoption of 60 available technologies and practices from 2003 to 2012.
- Adoption defined as features bought on new trucks purchased by the fleets. Any feature must have been on at least 5% of the trucks bought in that year to be considered "adopted". Research and development protototypes or early field test components were not part of this study.
- Retrofitted components were not considered as adoption for the purpose of this study, but may be a subject for future analysis.
- Compare these results with real world fuel economy.
- Deliver tailored benchmark reports to participating fleets and an aggregated report to the industry.

Various fleets were invited to participate based on the criteria discussed above. CR England, Challenger Motor Freight, Con-way Truckload, Frito Lay, Gordon Trucking, Ryder, Schneider and Werner, representing 75,000 tractors and 130,000 trailers chose to participate in this analysis and contributed financial resources as well as their time to the effort. A data collection document was prepared to collect the information needed to complete the analysis per the scope of work. Fleets identified a lead person and other key fleet individuals for the study team to coordinate their efforts and help the NACFE complete the study. Confidentiality of information was a high requirement for the study team and the information collected was only used by them.

Figure 6: 2013 Study Fleets

Between June 20, 2011 and September 30, 2011, the study team visited all eight fleets in the inaugural study to conduct the critical data collection for the analysis. Each visit included two days of discussions and site tours with multiple fleet participants. The data collection document was populated, discussions were held concerning various technologies adopted and best practices were shared concerning the fleet's fuel management operations. Day 2 included the confirmation of the validity of the data, deep dives with others, on best practices and a report out by the study team to the fleet's upper management. This report out offered a summary of the data, identification of technologies where the fleet demonstrated leadership, the best practices observed and some early recommendations to take even more actions.

The first NACFE Fleet Fuel Study report was announced at the American Trucking Association Technology and Maintenance Council Annual Meeting in February 2012. In the fall of 2012, Bison Transport and United Parcel Service were included in the study for the first time and all original eight fleets' submitted data for 2011 and 2012. This report, the 2013 update, now includes ten fleets and adds two years to the original work.

Some high level demographics of the combined fleet in the study population are.

- Seven generally for-hire carriers, two private fleets and one primarily leasing fleet.
- 40,783 tractors and 125,711 trailers were included in the data set; only the units where the fleet purchased fuel during the ten year study period. Leased trucks, new fleet acquisition equipment and company trucks driven by contractors who purchased the fuel were eliminated.
- These tractors drove 4,457,819,812 miles in 2012 averaging 109,306 miles per truck.
- The total gallons of fuel consumed by these trucks in 2012 were 673,339,395.
- 6,569 tractors operated pulling refrigerated trailers, 15% of the population.
- Average age of the tractor fleet in total was about 3.52 years.

Data was analyzed during January and February, 2013 by the study team. A webinar was held sharing the preliminary findings with the participating fleets and the study team answered questions. Findings were created with respect to the adoption of these technologies by each fleet and by technology. They were then compared to the fleet wide fuel economy. Fleet-wide fuel economy for each company was calculated using real miles driven divided by gallons of fuel purchased from data the fleets provided per their International Fuel Tax Agreement requirements. This method of calculating fuel consumption across the population in the trucks is the best available means for a consistent comparable number. Detailed supporting data from the fleets was included in the data collection document and was used to validate the entire data set.

The findings shown below contribute to an aggregated perspective of all the fleets' experiences with technology implementations, some adverse consequences encountered when implementing technology and the best practices they used to manage fuel expense. The study will also offer insights for others who might be considering adopting some of these products and practices and give suppliers an understanding on how to best develop more successful products.

Findings

This report will address the following findings of this study.

- Results of 60 technologies by product
- 60 technologies by fleet
- Adoption and Fuel Performance
- Interesting Technology Accounts
- Best Practices in Fuel Management

Technologies' adoption by product

60 technologies and practices were included in this study, and no new ones were added for this first annual update. They were selected after review of other such studies and identified as having been available for some of the study period. Cost of technology was not a factor. For instance, practices, setting engine parameters and removing parts for aero have no or very limited cost. But automated transmissions, APUs and major aerodynamics can be quite expensive while still offering significant payback. Figure ZZZ shows a sampling of some of the features.

Figure 7: Some of the Technologies

Products still in development or in very early stages of product launch were not included. A list of the technologies and practices can be found in Appendix B. Adoption is described as the percent of a fleet's new truck orders purchased with that specific device or on the percentage of the trucks in that year that adopted the practices. This data then was aggregated to determine an overall adoption rate by technology and of these technologies by fleet. Appendix C shows the eight year adoption curves for all 60 technologies and practices.

The study period consisted of the ten years from 2003 to 2012. This timeframe included the following industry dynamics.

- Relatively stable good economic conditions from 2003 to 2008, when the economy faltered and tonnage hauled dropped sharply. 2009 to 2012 showed again low rates of freight movement with a small improvement in tonnage hauled in 2011 and again in 2012.
- Diesel fuel prices made a steady climb from $1.50 per gallon in January 2003 to $3.00 in 2006 and 2007. A sharp increase occurred in 2007, leading to diesel prices hitting a high of $4.72 on May 26, 2008. A sharp decline followed with fuel prices reaching $2.02 by March 23, 2009. This was followed by a steady increase to $3.33 at the end of 2010 and then averaging around $4.00 for 2011 and 2012 (US EIA).
- EPA engine emission rules were introduced in October 2002, essentially at the start of the study period and again in January 2007, the midway point. SCR engines were introduced in mid 2010.

The percent adoption of a technology is a measure of the rate to which fleets purchased the given technology or implemented the practice in any particular year. The goal was to determine the adoption in terms of each fleet's selection and use. Therefore, it is not weighted by the number of trucks purchased per year by the fleet. This then measures fleet decisions, rather than the number of trucks with the technologies. With this methodology, the decision made by the smallest fleet Frito Lay, who purchases about 100 trucks per year is has the same value as that of the largest fleet buying thousands of tractors and trailers each year. The calculations are as follows:

- Each Technology Adoption
  - % Adoption = (% of new trucks purchased with technology @ fleet A + % @ fleet B + …) / Number of Fleets (10)
- Technology Adoption across all Fleets
  - Total % Adoption = (% Tech Adoption #1 + % #2 + …) / Number of Technologies (60)

The 60 technologies were grouped into six categories: anti-idling, chassis, practices, tires/wheels, tractor aerodynamics and trailer aerodynamics. The year over year adoption by category is shown in Figure 7.

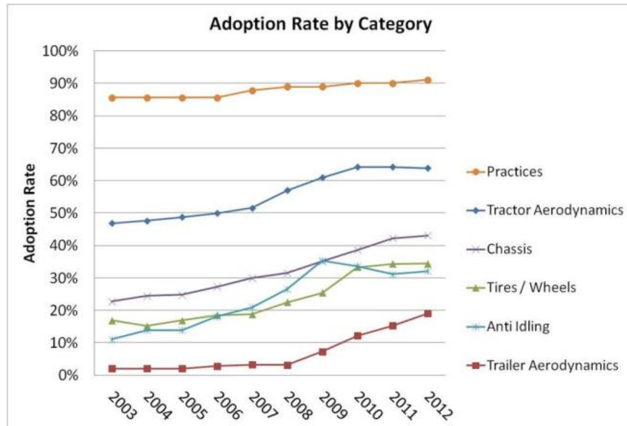

Figure 8: Adoption by Category

The fleet operating practices, including technologies such as speed limiting, utilization of routing software systems, driver training and others, were universally adopted at about 90%. Tractor aerodynamics included such items as aerodynamic hoods, mirrors and bumpers as well as chassis skirts, roof air fairings and cab extenders. For the ten fleets studied, these features were procured on an increasing ramp through 2006 then a steeper adoption in the more recent years. This may have been caused by the higher fuel prices.

The next category in descending adoption was the chassis area. This group included a move to automated manual transmissions, 4x2 and 6x2 axle configurations, synthetic lubrication, etc. Tires and wheels including wide-base tires, low rolling resistance duals, aluminum wheels and tire inflation and monitoring systems, have made the most dramatic improvement in adoption moving as a group from 15% to about 35%. Trailer aerodynamics is an emerging area with very low adoption with many of the products available only since around 2007. More recently fleets are choosing to add them 20% of the time on new trailers. And finally anti-idling devices, both diesel APUs and battery APUs, had a good ramp-up, but then a falloff of their adoption has occurred.

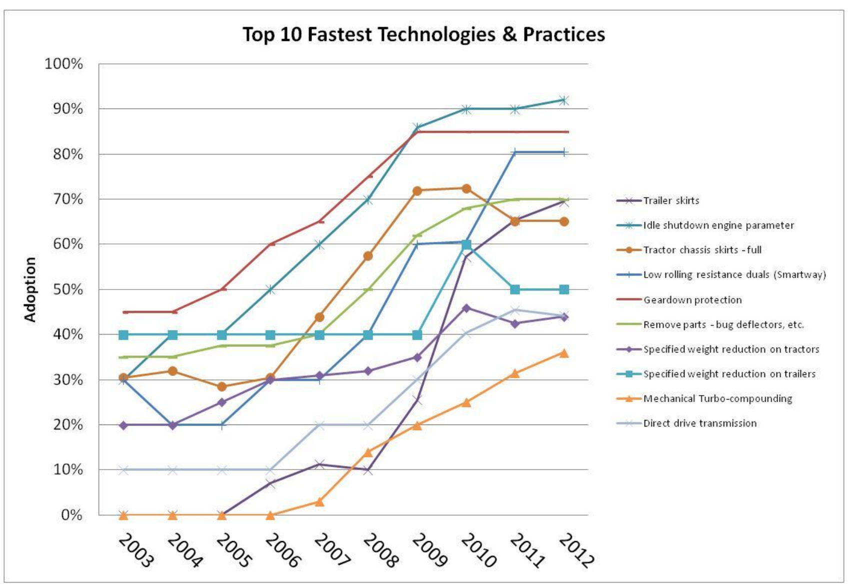

Figure 9: Fastest Adoption

Figure 9 shows the technologies or practices with the quickest adoption decisions over the study period. These ten features proved their effectiveness for these fleets in just a few years to significant adoption. Trailer and tractor skirts, low rolling resistance dual tires, idle shutdown and geardown protection, had the steepest purchase decisions.

Technologies' adoption by fleet

Another look at the adoption is by fleet. First, in Figure 8, a small group of technologies is shown where the adoption experience for each feature by fleet is characterized. Each fleet is shown as a column in this exhibit. There were 55 technologies and 5 practices studied.

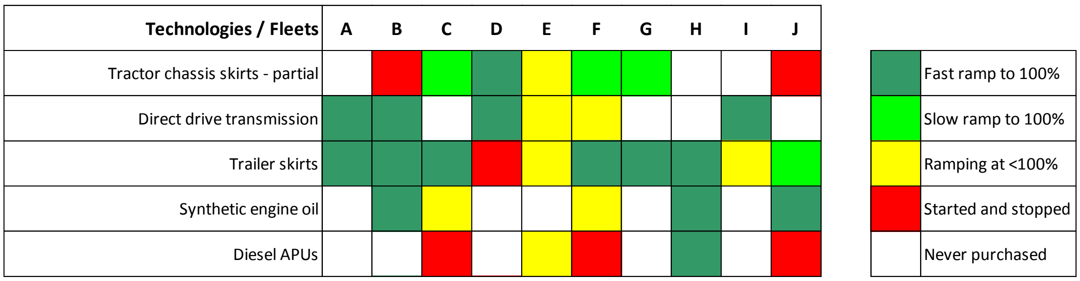

Figure 10: Example of Tech Adoption by Fleets

Here the technology is characterized as green; dark green or light green, if every tractor or trailer purchased has that feature on it now. Dark green identifies that the adoption had a fast ramp to 100% in two years or less. For instance when a fleet started buying aerodynamics mirrors, the first year they might have bought 50% of the trucks with aerodynamic mirrors and the second year they bought 100%, of their trucks with them, then it's a dark green cell on this chart. If it took them longer than two years, but they slowly ramped up to 100%, the feature is shown as light green. Yellow signifies that they still aren't buying 100% of the trucks with that technology, but it appears that they are ramping up to it. Red represents that over the timeframe of this study participants procured a feature on some of the orders, and then stopped buying the feature. And finally if it's white, the technology was never purchased. Of the 60 technologies, we identified 5 that were purchased at 100% by all fleets and 3, which no one adopted.

In Appendix D, the entire listing of technologies is presented in order of the highest adoption over time. For instance, synthetic transmission and rear axle fluid has been used by all fleets since the second year of the study period. This information can be useful as other fleets investigate which technologies to adopt as this represents real world experience by these eight fleets. Technologies at the top and those on the bottom of this list represent ones where their use is consistent amongst these carriers. Technologies in the middle are ones with less uniformity of adoption. Use of auxiliary power units for example included half of the fleets that have not adopted them, one that is ramping up, one that is buying all tractors with APUs and considers their payback a huge success and last, three that started, but no longer buys them. More, later as interesting technology accounts are presented below.

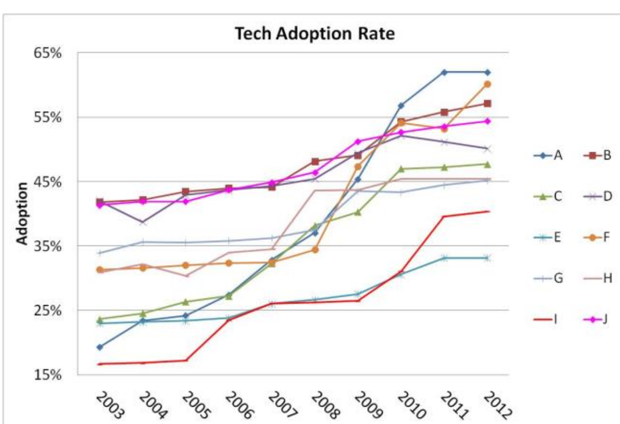

Figure 11: Tech Adoption over time by the Ten Fleets

As stated before, all of these fleets are in some stage of adoption of most of these technologies. Figure 9 shows the year over year adoption by fleet of all 60 technologies and practices. Here these ten fleets fell into three categories. Early adopters evidenced with high adoption rates in 2003 with a moderate increase over the rest of the study period (Fleets B, D, G H and J). The second group, Fleets E and I, are described as late adopters / slow followers with a continued moderate rate of adoption. Finally, are the aggressive adopters (Fleets A, C and F). This group includes a fleet F, who did not change much in their specifications from 2003 to 2008, but became one of the highest adopting fleets in a step change starting in 2009 to drastically include these features on their new tractor and trailer orders. Eight of the ten fleets now have very similar overall adoption percentages, even though as shown earlier, are buying different features.

Adoption and Fuel Performance

Figures 12 and 13 show an average of the adoption of the technologies across all of the ten carriers. This is represented by the dashed green line and shows adoption moving from 31% to about 50%. There is a moderately increasing slope from 2003 to 2007, and an increasing rate of adoption for the second half of the study period. This is driven by two items, the maturing nature of the products offered by suppliers and the challenges for these fleets with respect to increasing fuel prices and sustainability priorities. Of note, and demonstrated in Figure 12, is that the adoption rate continued to increase in 2009 and 2010, after the steep decline in fuel prices. The fleets commented that their dedication to continuing to buy these more fuel efficient trucks has paid off as the fuel prices have steadily raised again to $4.00 per gallon. The overall opinion from the fleets in the study was that fuel prices will continue to increase and that the days of “cheap oil” are over.

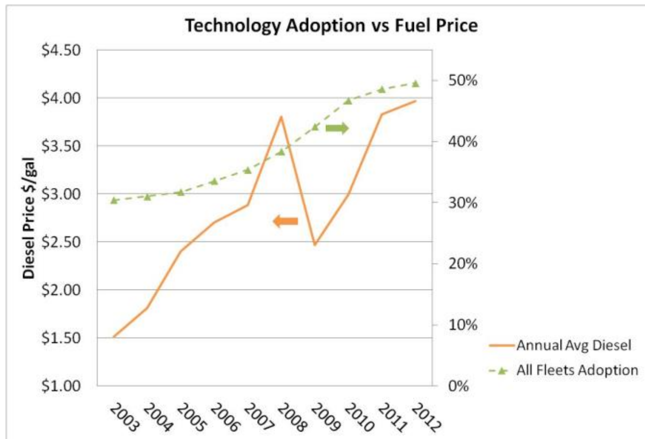

Figure 12: Tech Adoption and Fuel Price

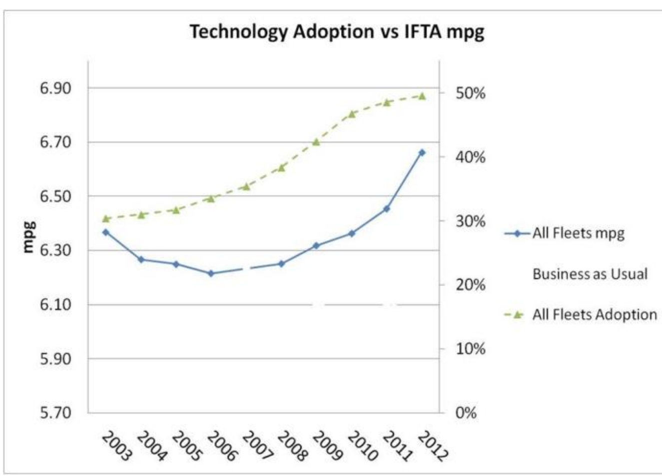

Figure 13: Tech Adoption and Fuel Performance

With respect to fuel performance (Figure 13), the study participants provided the total miles traveled by the trucks in the study and the total gallons purchased for each of the years in the study, as they reported under the IFTA reporting requirements. This data delivered a bathtub curve (blue line), with the average miles per gallon of 6.4 in 2003, dropped down to 6.2 in 2006 and then improving to 6.4 in 2010 and 6.7 by 2012 across the entire population. In summary, the study team concluded that the adoption of these technologies: a) has occurred, and b) contributes to a fuel economy increase as the level of adoption increases.

It is important to note that these fuel economy numbers are fleet-wide for that calendar year of 2003 and so on. That is a compilation of the fuel performance of all the trucks in the fleet at that time. For instance, in 2007, for a fleet with a five year trade cycle, the population would be comprised of trucks purchased and put into service in 2003, 2004, 2005, 2006 and 2007. That is different than the adoption which is the purchase percentage by feature on new truck purchases in that particular calendar year. The mpg line then should be a trailing metric to the adoption rate, in order to represent the effect on the fleet wide fuel economy of the features bought on new trucks.

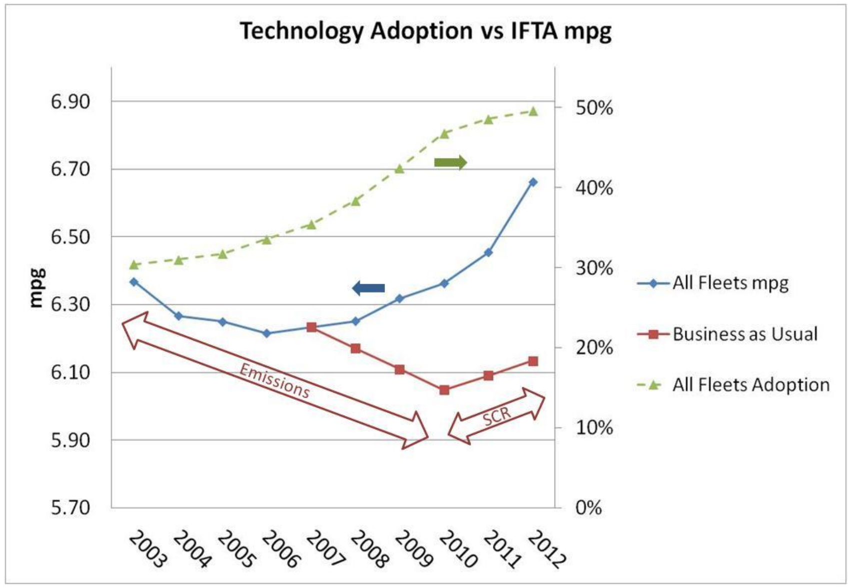

Figure 14: Business as Usual – Without Tech Adoption

The declining rate of fuel performance in miles per gallon, throughout the first half of the study period was analyzed and determined to primarily be driven by the introduction of Exhaust Gas Recirculation (EGR) engines introduced to meet the October 2002 EPA emissions requirements. Engine and truck OEM's were surveyed to develop a Business as Usual prediction (red line) with respect to the continued replacement with pre-EGR engines and the introduction of 2007 emissions. An algorithm was developed to predict the fuel performance from the base power plant in order to understand the probable fuel efficiency of trucks had the fleets not adopted any of these technologies. In 2010, for another emissions regulation, Selective Catalytic Reduction (SCR) engines were introduced. After again, surveying the industry and accounting for the use of Diesel Exhaust Fluid, an increase in fuel efficiency occurred after these engines were introduced. This increasing rate will continue as the fleets introduce them into their fleets.

Interesting Technology Accounts

In this section, insights will be shared for nine interesting technologies (IT). The adoption experience for the technology by each fleet is shown in Appendix D.

IT#1: Practices

Nearly all fleets have adopted the five management practices that were asked about in the study. The range of aggressiveness in their approach implementing each is wide. For instance, some fleets limit speed to about 62 mph, with most allowing for short periods of a soft pedal up to 65 mph or higher for passing in traffic. Driver training initiatives and incentives programs vary, with the most successful only measuring those actions that the driver can actually affect; speed, % idle, % in top gear, etc. One fleet has a substantial training curriculum for all drivers, while another uses a driver simulator to help train operators in fuel efficient driving practices. A future study could investigate various characteristics and success of these practices in a more detailed manner.

IT#2: Tractor Aerodynamics

The ten fleets in the study have adopted most if not all of the available tractor aerodynamic features. Most of the technologies had a fast ramp to 100% adoption. Truck OEMs are fine tuning their designs with dozens of small changes to various components. For instance, OEMs are filling gaps between bumpers and fenders that can give a couple tenths of a percent fuel economy improvement. Fleet leaders shared some challenges in making sure each feature is available on their trucks as quickly as possible. An example would be a part added at the rear of the air deflector pod on top of the cab between the cab extenders to seal the area between the tractor and the trailer. Most tractor OEMs have this part, but one fleet shared that it was missing on its pilot model and added only when it was noticed on another fleet's vehicle. That feature is probably worth a couple hundred dollars a year in fuel. More advances are expected in this area that will require attention by fleets to ensure they are maximizing this opportunity.

One fleet shared, that one challenge to adopting aerodynamic tractors was their resale value. With their planned turnover within 3 – 4 year's time, they decided to purchase classic tractors in 2004 and 2005. This strategy had a fleet wide average fuel economy impact of about 0.5 mpg decrease. Another insight is the need for the truck OEMs and component suppliers to develop these features for all tractor configurations that could benefit from them. One fleet needed to work with a supplier and add chassis skirts after OEM production of the vehicles, because they were not available on a short wheelbase daycab. This forced higher cost and lower potential reliability / durability.

IT#3: Trailer Aerodynamics

Most trailer aerodynamic devices had limited supplier product offerings for most of study period. In other words, this is an area where many of these devices simply have not been available during the whole eight years of the study. For instance, boat tails on the backs of trailers have only become available starting in 2007. Trailer skirts have had quick adoption in the past 5 years, accelerated by the California Air Resources Board requirements. Fleets shared varying degrees of real world fuel economy performance from 2 to about 5% for these devices. These ten fleets had an average tractor to trailer ratio of 1:3.08. Return on investment calculations must factor in the lower miles travelled by each trailer. The fleets shared that it is very difficult to devote a specific trailer design to their higher mileage routes and with so few in dedicated use, they must assume that any trailer in their fleet will be pulled behind any tractor. Therefore, if the fleet is using 100,000 miles driven per tractor in their return on investment calculations for their decision-making, trailer aerodynamics' worth must be justified using fuel savings for only 33,000 miles.

New concepts are being developed in the trailer aerodynamic arena. One such device is a trailer undertray / bogie fairing in place of trailer side skirts and boat tails. The development of competing concepts may actually slow overall adoption as fleets decide which devices are best for their unique fleet situation. Aggressive management of tractor to trailer gap by fixing 5th wheel slides in the optimal position and efficient cab extenders seem to have replaced adoption of various gap devices such as nose cones. One reason for this is the fact that a device mounted to the tractor cab benefits from the higher mileage and associated payback as mentioned above. Clearly there's not a lot of adoption of these technologies, making trailer aerodynamics fertile ground for introduction and benefit. The NAS study estimated that the fuel consumption improvement available today for trailer aerodynamics is 5.5% and could grow to 11.5% in just a few years.

IT#4: Tires and Wheels

Much development has occurred in rolling resistance of tires over this study period. All fleets have adopted low rolling resistance duals with two fleets having gone exclusively to wide-base tires for weight reduction and fuel economy and another three in some level of purchase. One fleet has no plans to go wide-base as they believe the fuel savings do not overcome their cost difference. All fleets seem to believe tire and wheel availability and other historical issues with wide-base tire adoption no longer exist. They also all mentioned weight challenges with heavier tractors due to emissions equipment and a move to denser loads have driven them to consider wide-base tires for their weight savings potential. Aluminum wheels continue a good acceptance by these fleets, driven by their weight savings and resale value.

IT#5: Tire Inflation

Correct tire inflation is important to good fuel economy with all fleets having programs to ensure their drivers and maintenance facilities are doing all they can to be sure all tires have adequate pressure, all the time. The study asked about the adoption of four technologies to assist in this maintenance with only tire pressure inflation on the trailers having much adoption. There are differing experiences with respect to the reliability of tire inflation systems, but in summary they seem to have improved on systems procured in the past few years. One concern noted with tire inflation systems was that a driver may over-rely on the tire inflation system and continue to drive on a flat tire expecting it to self inflate, only to have a blowout later.

Other devices were referenced by a few fleets, including a unit which measures the tractor's and trailer's tire pressure as it drives over a device returning to the fleet terminal. This could greatly assist in a fleet's ability to monitor, take action and continue to educate drivers and maintenance technicians on the importance of correct tire inflation. There does not seem to be one technology or practice emerging. A fleet can dedicate its efforts to managing correct tire pressure or to procuring systems that will monitor and inflate on their own.

IT#6: 6x2 Package

A few fleets shared that they have adopted or are testing a 6x2 package of features, which includes a dead axle, direct drive transmission and wide-base tires, with trailer tires on the dead axle. This combination in one case is showing about 0.4 mpg or 6% fuel consumption performance improvement. This combination also delivers weight and cost savings. The fleet with quick adoption shared that this requires some training and driver management, but that experience in two winters across many driving conditions has proven the worth of this technology. The primary concern for its use is a lack of traction with only one single drive axle. Much development is underway to improve the traction of these tractors and it is expected that this issue will be significantly mitigated soon. In nearly all cases, the fleet reported that the trucks should not have been operated in the conditions when they got stuck, due to higher risk of damage. That is in a snow storm or on off-road areas. Another fleet has been quite aggressive in replacing 6x4 tractors with 4x2s.

IT#7: Automated Transmissions

Most fleets have purchased small quantities of automated manual transmissions for driver recruiting, lower maintenance and better fuel economy. All fleets experienced various problems with products built in the early 2000s and either stopped buying them or severely limited their purchases per year. Some cited resistance by operators to move from manuals to any form of automatic transmission and with long haul operations, where most of the fuel is consumed in the top two gears, most doubt any acceptable return of investment. For city and regional duty cycles, with more stop, start and gear shifting there is much more likelihood of a reasonable payback. Fleets confirmed that the recent generation of "smart" automated manuals has solved early problems with shifting, reliability, driver acceptance, etc. and that adoption rates will likely increase in the next few years. One fleet has now made the switch to 100% of their new tractor purchases having automated manual transmissions and drivers and maintenance technicians are reporting high levels of satisfaction and acceptance.

Fully automatic transmissions are not being considered at this time by these fleets, but research and development continues by many suppliers and adoption in numerous vocations of trucking, such as garbage trucks, school buses and dump trucks, where automated transmissions are growing in use.

IT#8: Weight

All fleets discussed the need to lower tractor and trailer weight. They cited the increased tractor weight due to the addition of emissions equipment in 2002, 2007 and 2010. The also mentioned higher demand for full sleepers and other driver amenities, the requirement for long life trailers and the increased density of freight due to improved packaging, etc. as contributors to the problem. Also, many of the features included in this analysis add weight as well, e.g. aerodynamics devices. The lower the weight, the less fuel it requires to move the load, but historically lower weight components cost too much and in some cases were less reliable than the benefit in fuel savings.

As shown earlier, tires and wheels can contribute to weight savings and the study investigated three other opportunities for weight savings; specific tractor and trailer features and the opportunity to downsize engines, possibly 15L to 13L, for weight reduction. These fleets have quickly adopted some features to trim overall weight. An example on the tractor is that most of these fleets have moved to horizontal exhaust, saving a minimum of 75 lbs and as much as 200 lbs. As clean as the exhaust now is from these new trucks, they no longer have to employ vertical tailpipes to divert the exhaust above the trailer. Trailer features include composite floors and doors. Downsizing the engine has raised many concerns including power, torque, durability, etc. but these fleets actually cited experiences with better fuel economy with the larger engines as a reason to stay big with their engine choice. Most engine manufacturers have recently launched new 12 and 13L powerplants and engine downsizing might become more practical for these trucks in the near term.

IT#9: Auxiliary Power Units

The final interesting technology is APUs. The study team identified three actions possible for reducing the amount of time a truck idles: battery APUs, diesel APUs, and automatic idle shutdown. Almost all fleets reported using engine idle shutdown and have incorporated diesel fired heaters for cab heating during the winter. The main issue requiring power during layovers is air conditioning in the summer. For diesel APUs, one fleet in the study had full adoption fast, three started and then stopped, one is purchasing some of its trucks with them and the five remaining only tested small quantities and are not planning to purchase units on their orders. The primary reason the three fleets stopped was that they just didn't perform from a maintenance standpoint. The maintenance costs became expensive; one case cited in excess of $100 per month per truck for these APU trucks.

At the opposite extreme, one fleet considers diesel APU introduction an incredible success, with the main contributor being significant savings in maintenance on the main drive engine of the tractor. They compared the APU trucks to non-APU trucks with respect to engine maintenance and saw an improvement over the life of the truck (800,000 miles) of about a penny a mile in maintenance savings.

This equates to around $8,000 in main engine maintenance contributing to the return on investment of the purchase of diesel auxiliary power units. That combined with the fact that they didn't have the APU maintenance issues identified by the other fleets, whether it was the particular supplier used or how they integrated it, they saw APUs as a major success. They continue purchasing 100% even with the added expense of a diesel particulate filter on the APU.

And finally, a few fleets had bought some battery APUs, with the belief that they could actually be the most viable long-term solution. Because of battery cost and the control issues, and challenges related to the connection between the battery APU and the truck, the feeling is that more development is needed before there's much more acceptance of this technology. During the past few years, these systems are beginning a ramp that is expected to increase and become a popular anti-idling solution.

Best Practices in Fuel Management

During the data collection, the study team conducted a best practices exploration at each fleet. The following are nine best practices we identified being employed by some of these fleets to manage and lower their fuel expense. They are offered here as possible processes for adoption by other fleets and to help suppliers and other industry stakeholders better support the fleets in these efforts.

BP#1: "MPG" Committee

Definition – Form a fuel management or "MPG" committee that creates a fleet-wide understanding of freight efficiency and fuel economy, cultivates ideas, prioritizes them, makes decisions, implements actions and assesses their success later. This team will help create a "culture" within the fleet that will take on the challenge of fuel expense reduction, be creative in their approach and involve everyone in the effort.

Keys

- Structured – at least monthly meetings, with good trust developed and teamwork. Use agendas, prioritized lists, timelines, etc.
- Diverse, representatives from all functions influencing mpg.
- Respected throughout the company and becomes an integral part of the management practices, with accountability between divisions / regions.
- Can be led by any function that has some responsibility for fuel, and can develop cross functional trust, acceptance and engagement.
- Encourage suppliers to participate and present to the committee
- Return on investment calculations have input from all affected parties and are validated by finance, which also has participation on the committee.
- Together makes recommendations to Senior Management.
- Continuously assess prior decisions and act if needed.

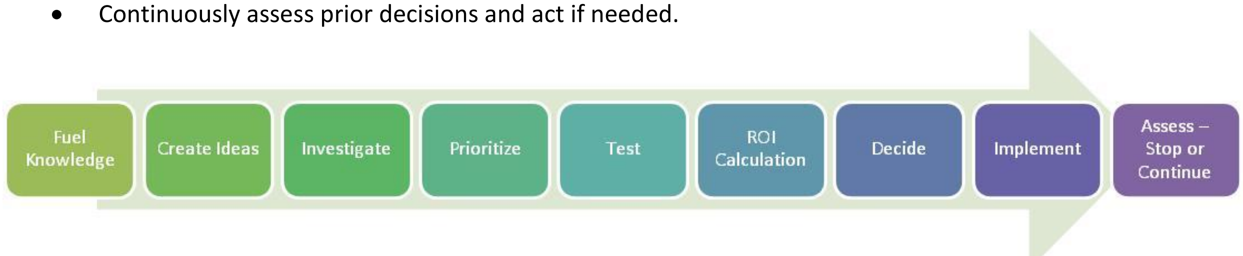

Figure 11: Technology Implementation

BP#2: Competent Fleet Fuel Team

Definition – Employ a robust process to identify, approve, prioritize resources and execute mpg improvement initiatives.

Keys
- Identify and develop a professional cross functional fleet team.
- Include equipment and operations experts and data-driven process-oriented members.
- Engage key stakeholders on the teams.
- Focus on gallons reduced rather than dollars saved.
- Have a gate process to manage the projects while still avoiding analysis paralysis.
- Use OEMs, suppliers and consultants to support the efforts. A vendor evaluation process helps level expectations and encourages improvements.
- Uses a fuel protocol to set the expectations around validation of ideas.
- Implement a robust project audit review; one year after the product was adopted.
- Demand discipline to the processes, involve functions and engage all levels of management.

BP#3: Lifecycle Cost Analysis

Definition – Some fleets have a core competency to understand the overall cost of ownership with respect to reliability and uptime. A similar approach can be used to identify and make decisions on fuel economy.

Keys
- Tractor and trailer reliability is critical to fleet success. The first efficiency measure is uptime – is the truck capable of running?
- Some fleets have very sophisticated systems to track the reliability of every component on the vehicle across their entire population of equipment.
- This system allows them to make decisions on hundreds of components for reliability cost versus purchase cost.
- Such a system could be developed for each component's contribution to fuel performance.
- Testing, validation and vehicle monitoring would have to be significant to thoroughly understand each component's contribution.
- The development of such a system could be a future NACFE project to be executed.
- Telematics, etc. could be utilized to support the system.

BP#4: Focused Specifications

Definition – A commitment to a limited set of standardized equipment with a small number of suppliers can help enable fuel management success. Some of the fleets had procured trucks, engines and trailers from a vast variety of suppliers, while others were single sourced with one specification. There are large challenges with both, and having a focused few seems to deliver the best opportunities.

Keys
- Create long term, in depth and high trust relationships with tractor, trailer and component suppliers. Become each others' true partners in order fulfillment and product development.
- Removes a great deal of variables when studying, testing and implementing new ideas.
- Simplifies driver training and incentive program success.
- Baseline vehicles are more valid in TMC / SAE vehicle level fuel economy tests.
- Easier to identify outliers to deal with excellent and poor mpg performance.

- Creates higher level of integration when focusing on standardized trucks.
- New product training and maintenance is controllable.
- Lowers cost and improves leverage. Get a head start on new products.
- Requires outreach into the industry to constantly assess the strength of the "other" suppliers' products, since the direct experience for the majority is less.
- Should evaluate, procure and test these other products on a periodic basis.

BP#5: Driver Education and Incentives

Definition - Implemented a driver training and ongoing process to improve mpg by driver and truck. A robust process at one of the benchmarked fleets delivered a 6.2% sustained improvement in fuel consumption over time.

Keys
- The worst to best drivers can be 25+% in fuel performance, but it's challenging to raise the entire average.
- Use detailed data collection to deeply understand the base.
- Simple, early mission – "help the field burn less fuel".
- Be disciplined in data collection and set a bold goal (E.g. 5.5% reduction in fuel burned).
- Focus on making the majority of drivers and trucks better, rather than only deal with the poorest performers.
- Pilot the program at one location.
- "Brand" the effort, and pick and engage best performers (drivers, mechanics, managers and support resources) to implement and deliver the program.
- Engage a professional supplier to execute the training or decide to create and execute the program internally.
- Create the necessary tools and processes: Training with practice driving, driver and truck reports, Truck Intervention Processes, High Performance Route selection, etc.
- Ongoing, cultural work after implementation team has been disbanded.
- Create a strong incentive program to ensure commitment over time.

BP#6: Dedication to Testing

Definition – Demand suppliers conduct TMC/SAE tests, and then conduct vehicle level validation tests using consistent, repeatable methodologies.

Keys

- Pre-screen technologies via supplier delivered TMC/SAE tests.
- Then, validate with in-house testing at high accuracy rates using the test methodology selected by the fleet and standardize on it.
- Dedicate engineers, technicians and drivers for this testing and document routes, roads, traffic congestion, temperatures, etc.
- Compare "high confidence" results with supplier provided ones for learning and sharing with the suppliers for improvement.
- Document all testing in order to correlate results to real world by product and by supplier – supplier test benches, to TMC/SAE tests and to real world freight movement.
- Network with other fleets to share testing methodologies and practices.

- During this study, the team found essentially unique test protocols at all eight fleets. A future project could be to compare and contrast these developed test methodologies in order to attempt to standardize on a few more common methods.

BP#7: Outstanding Maintenance

Definition – A commitment to excellent maintenance practices helps ensure the equipment is operating efficiently and at low operating cost, also reduces fuel use.

Keys

- Well maintained equipment continues to deliver the fuel economy that was expected when the tractors and trailers were new.
- Trucks that are clean and well maintained perform better.
- Many small maintenance actions, such as tire inflation, alignment, air leaks, compressor, air conditioning, etc. can add up to as much as an entire mpg improvement.
- One example shared by a fleet includes the Diesel Particulate Filter cleaning at around 200,000 miles for around $400. Fleets state that they have seen a 0.1 to 0.2 mpg improvement with this cleaning. This action delivers about a 2 month payback in fuel savings.

BP#8: Ensure Latest Features

Definition – Conduct pilot reviews of the first vehicle from a new order at the truck builder to ensure the vehicle contains all the fuel efficiency features expected.

Keys

- Be sure the tractor and trailer specifications include all the features that are desired. Investigate small design changes and improvements within the specifications.
- Work diligently to conduct a pilot review at the OEM factory after they have built one truck before the full order is assembled. This can be done with each set of significant spec changes.
- Travel to the plant to witness the review.
- Ensures that the design meets the fleet's needs.
- Sign off on electronic features for fuel economy, such as engine parameters. Ensure responsibility for maintaining these is clear throughout the deliver process; at the factory, truck specialty center, dealer, fleet location, etc. If there is a software change during this process, the process should confirm that the agreed upon settings are maintained on the trucks / engines.
- This process, at one of the fleets, helped find an air deflector that was available, but had not been implemented on a fleet's truck. The change was made prior to the rest of the trucks being built and likely delivered 0.3% fuel economy improvement.

BP#9: Exploit Ton Miles/gal

Definition – Freight efficiency is really about moving more freight, defined either in terms of tons or cubic feet of freight, more miles per gallon of fuel. Weight savings and maximizing the space in the trailer benefit this refined freight efficiency calculation. One fleet maximizes their opportunity to haul double 53 foot trailers in western Canada. 21% of the miles travelled by their tractors in 2012 were hauling two 53 foot trailers.

Keys

- Use miles per gallon as a measure, today to help focus fuel efficiency improvement efforts.

- Remember that freight efficiency is about moving the most freight possible.
- Take advantage of opportunities and look forward to the future.
- Both of the Canadian fleets in the study are procuring all new trailers with the equipment that enables them to be in doubles and have retrofitted many of their existing ones for this purpose.

Fuel Performance from Adoption

As shown earlier, the adoption of each of the technologies and practices on new tractors and trailers in each year from 2003 to 2012 was compared against the actual fleet-wide fuel economy during each of the year. In summary,

- All ten fleet's average adoption over the study period moved from 31% to 50%.
- The average mpg for their trucks in the study group, calculated by dividing the total miles travelled by gallons of fuel purchased by year as reported under the International Fuel Tax Agreement (IFTA) decreased through 2008, then drastically improved.
- Average fuel economy across all ten fleets for 2012 was 6.66 mpg compared with 6.36 for 2010.

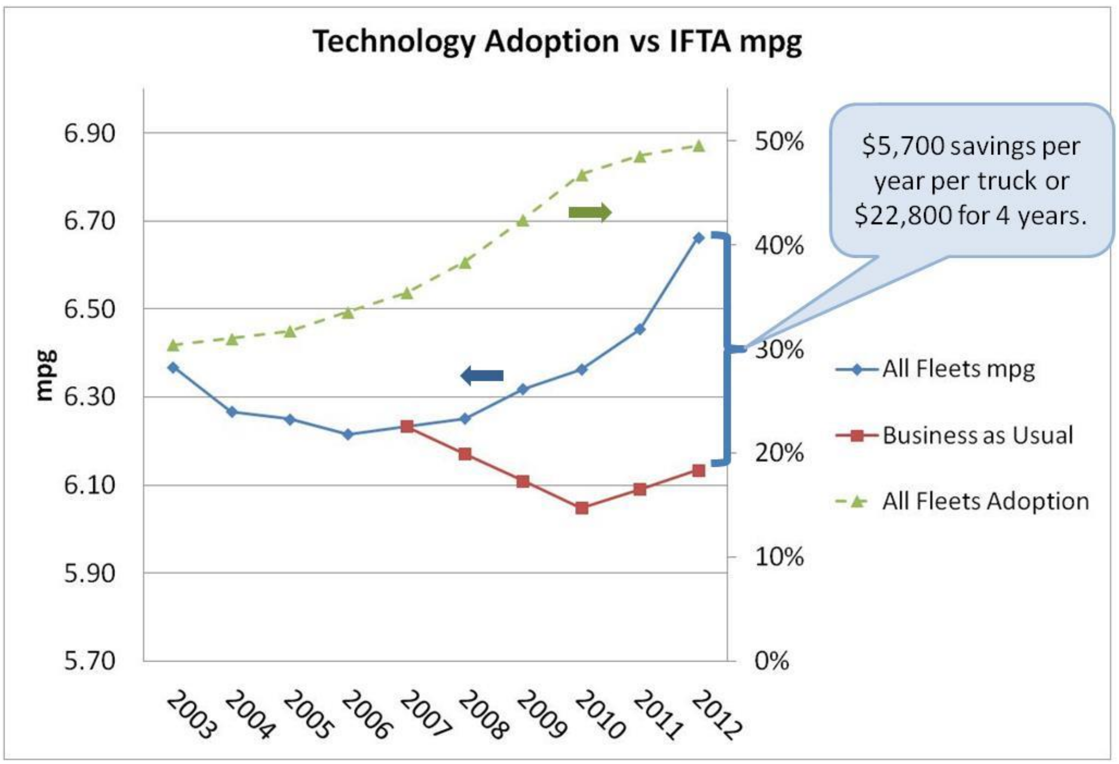

Figure 16: $5,700 per Year per Truck Savings

The resulting impact over the population of trucks at these fleets for 2012 then can be calculated as:

- Combined miles driven = 4,457,819,812.
- 57,760,101 gallons saved; which equates to 1,416 gal/truck.
- $231,040,404 saved at $4/gal diesel; or $5,665/truck.
- Over 4 years, generally the shortest time to resale for these fleets, the total savings are $22,660/truck.
- In 2010, the savings were $3,362.16 giving a dramatic improvement of $2,302.96, in just two years.

The past and expected continued ramp of these technologies will contribute to lower the fuel consumption of these vehicles as more trucks enter the population for the fuel economy calculations. The NACFE is committed to completing this effort annually and increasing the number of fleets participating to make the results as robust as possible.

Conclusions and Recommendations

After analyzing all the data from the study group, the following conclusions were reached.

- The adoption of these technologies has been significant in improving the operating cost for these fleets.
    - Almost 9% in REAL WORLD AVERAGE fuel economy savings.
    - Savings are worth $22,800/truck for the shortest owner life of 4 years.
- Validating the success of any individual technology or practice is challenging.
- Technology implementation can vary depending on the supplier selected and the discipline to make it work in each fleet's operation.
- Suppliers must develop variations of their products to best fit differing duty cycles and specific fleet needs.
- Discipline to creating and sharing credible data is essential to product development and adoption.

The following are the NACFE's recommendations based on the results of the study.

- Create a "Culture" for fuel management expertise.
- Develop a structured "MPG" leadership committee.
- Achieve excellent program management of projects.
- Pick a test method and execute it.
- Provide training and incentives for drivers, maintenance and other support employees.
- Intervene for poor performing trucks and drivers.
- Have deep relationships with suppliers.
- Limit variation in the fleet.
- Evaluate and adopt technologies continuously.
- Use simple and visible key operating metrics.
- Reduce vehicle weight whenever possible.

The increasing implementation of these recommendations by fleets and the support for them by suppliers, industry associations, academia, research labs and government organizations can drastically improve the freight efficiency of North American goods movement.

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Appendix A

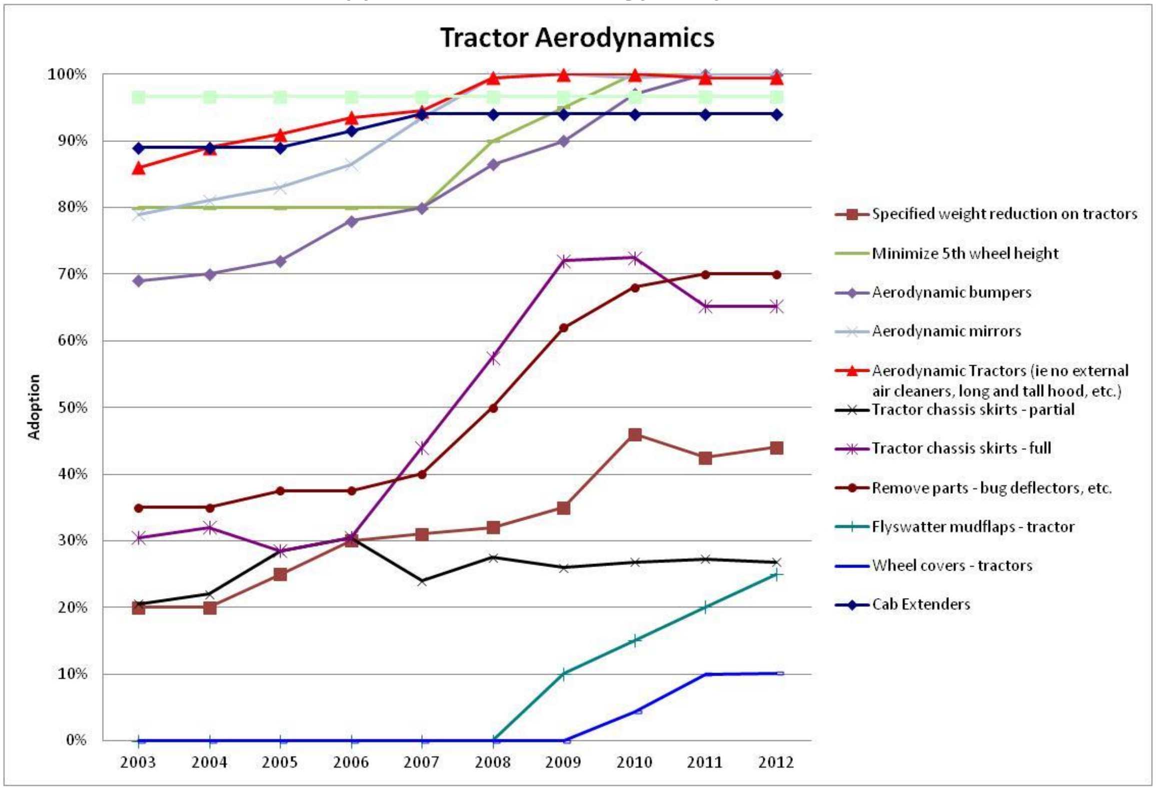
Appendix B: Average Technology Adoption Rates – all fleets

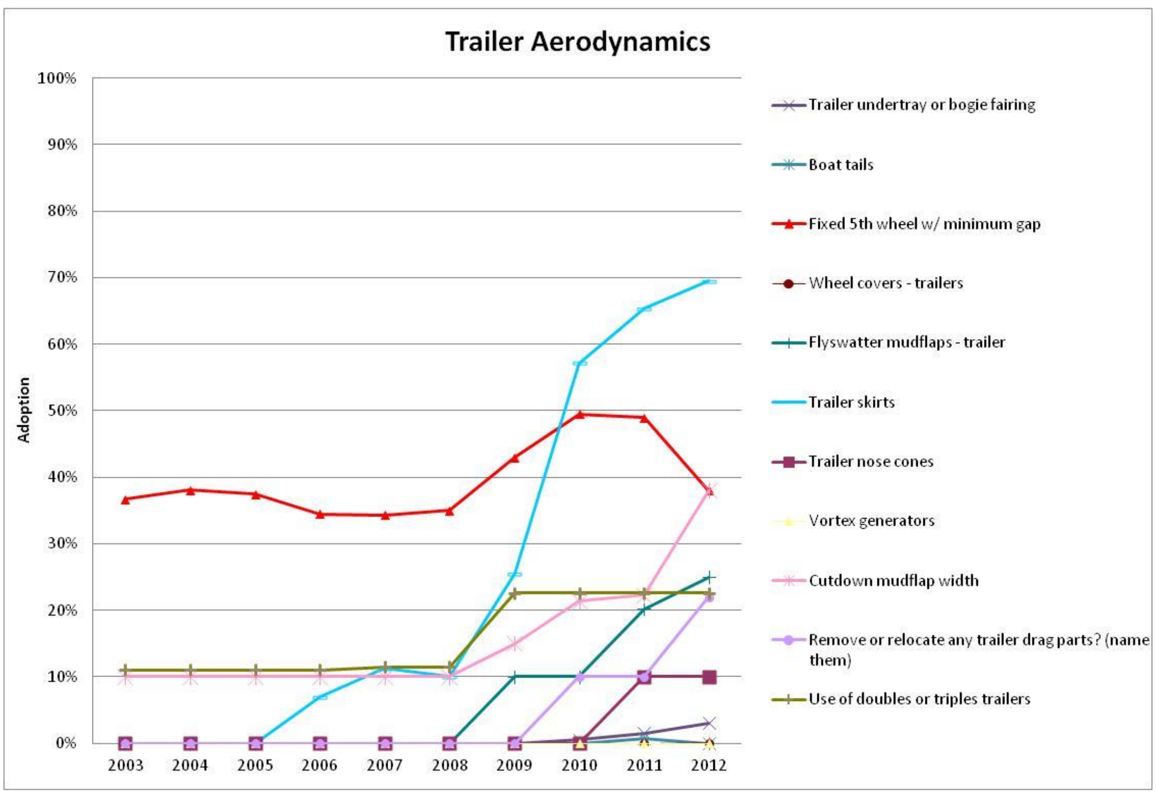
% with the following technologies	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Aerodynamics										
Aerodynamic Tractors (ie no external air cleaners, long and tall hood, etc.)	86%	89%	91%	94%	95%	100%	100%	100%	100%	100%
Tractor chassis skirts - partial	21%	22%	29%	31%	24%	28%	26%	27%	27%	27%
Tractor chassis skirts - full	31%	32%	29%	31%	44%	58%	72%	73%	65%	65%
Aerodynamic bumpers	69%	70%	72%	78%	80%	87%	90%	97%	100%	100%
Aerodynamic mirrors	79%	81%	83%	87%	94%	100%	100%	100%	100%	100%
Remove parts - fender mirrors?	14%	14%	14%	10%	10%	30%	30%	30%	25%	25%
Remove parts - bug deflectors, etc.	35%	35%	38%	38%	40%	50%	62%	68%	70%	70%
Full height roof air fairing	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%
Cab Extenders	89%	89%	89%	92%	94%	94%	94%	94%	94%	94%
Fixed 5th wheel w/ minimum gap	37%	38%	38%	35%	34%	35%	43%	50%	49%	38%
Minimize 5th wheel height	80%	80%	80%	80%	80%	90%	95%	100%	100%	100%
Flyswatter mudflaps - tractor	0%	0%	0%	0%	0%	0%	10%	15%	20%	25%
Wheel covers - tractors	0%	0%	0%	0%	0%	0%	0%	4%	10%	10%
Specified weight reduction on tractors	20%	20%	25%	30%	31%	32%	35%	46%	43%	44%
Wheel covers - trailers	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Flyswatter mudflaps - trailer	0%	0%	0%	0%	0%	0%	10%	10%	20%	25%
Trailer skirts	0%	0%	0%	7%	11%	10%	26%	57%	65%	70%
Trailer undertray or bogie fairing	0%	0%	0%	0%	0%	0%	0%	1%	2%	3%
Trailer nose cones	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%
Vortex generators	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Boat tails	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
Cutdown mudflap width	10%	10%	10%	10%	10%	10%	15%	21%	22%	38%
Remove or relocate any trailer drag parts? (name them)	0%	0%	0%	0%	0%	0%	0%	10%	10%	22%
Use of doubles or triples trailers	11%	11%	11%	11%	12%	12%	23%	23%	23%	23%
Tires / Rolling Resistance										
Tire pressure monitoring - trailer	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%
Tire pressure inflation - trailer	1%	1%	1%	5%	7%	22%	22%	32%	33%	32%
Specified weight reduction on trailers	40%	40%	40%	40%	40%	40%	40%	60%	50%	50%
Low rolling resistance duals (Smartway)	30%	20%	20%	30%	30%	40%	60%	61%	81%	81%
Wide based tires - tractors	0%	11%	10%	10%	11%	11%	19%	19%	22%	27%
Wide based tires - trailers	10%	1%	10%	10%	11%	11%	11%	19%	20%	20%
Aluminum wheels tractors	60%	60%	60%	61%	61%	71%	71%	82%	77%	82%
Aluminum wheels trailers	28%	19%	28%	30%	30%	30%	32%	51%	51%	42%
Tire pressure monitoring - tractor	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Tires filled using Nitrogen	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Appendix B (Cont.): Average Technology Adoption Rates – all fleets

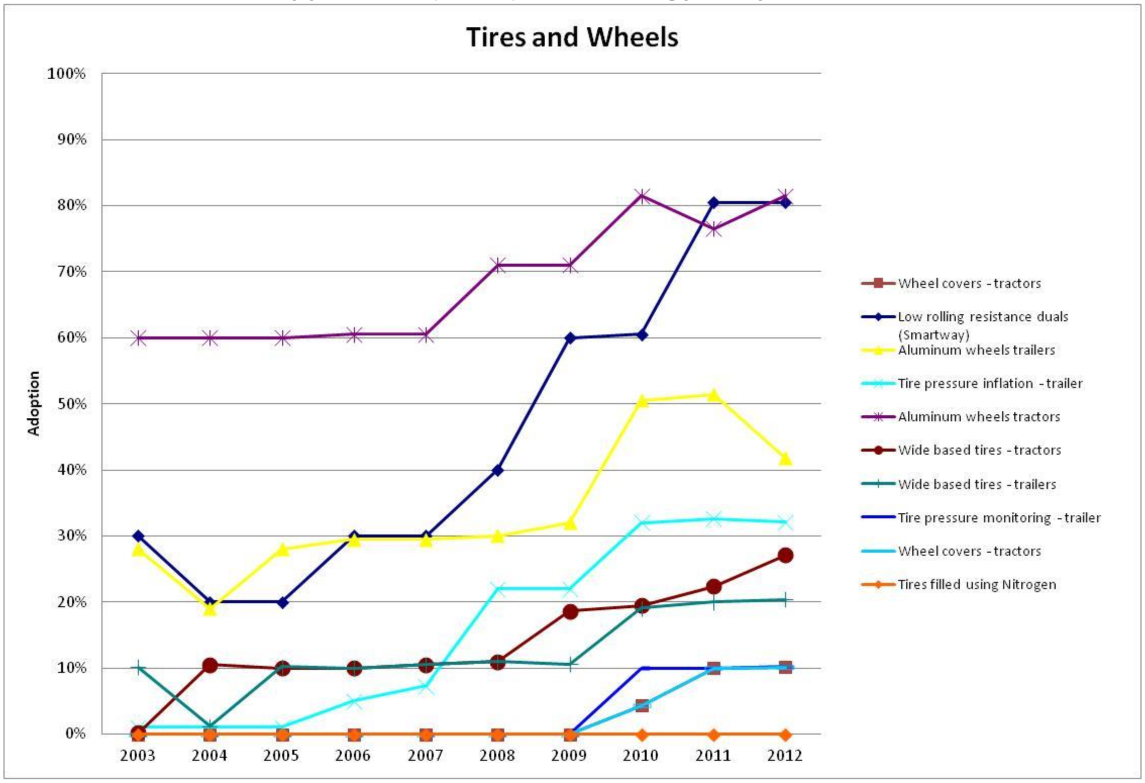
% with the following technologies	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Chassis										
Move from 6x4 to 4x2 tractor specs	1%	0%	0%	2%	3%	3%	3%	9%	9%	9%
Spec dead (6x2) axles	0%	0%	0%	0%	0%	0%	5%	10%	10%	11%
Move from manual to Automated manual transmissions	4%	15%	11%	16%	15%	19%	22%	29%	28%	29%
Move from manual to Automatic transmissions	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
Downsize engine (e.g. 15L - 13L)	4%	4%	4%	4%	8%	8%	10%	27%	40%	38%
Direct drive transmission	10%	10%	10%	10%	20%	20%	30%	40%	46%	44%
Synthetic axle lube	88%	98%	98%	98%	98%	98%	98%	98%	98%	98%
Synthetic transmission oil	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Synthetic engine oil	20%	20%	25%	30%	30%	30%	30%	30%	40%	40%
Fuel additives	0%	0%	0%	0%	1%	0%	0%	0%	10%	10%
Engine parameters set for fuel economy	84%	84%	84%	94%	94%	94%	94%	94%	94%	94%
Geardown protection	45%	45%	50%	60%	65%	75%	85%	85%	85%	85%
Predictive cruise control	0%	0%	0%	0%	3%	6%	19%	25%	31%	43%
Change vehicle gearing	40%	40%	40%	40%	60%	60%	60%	60%	70%	70%
Use of clutched air compressor	0%	0%	0%	0%	0%	0%	10%	15%	15%	15%
Mechanical Turbo-compounding	0%	0%	0%	0%	3%	14%	20%	25%	32%	36%
Anti Idling										
Idle shutdown engine parameter	30%	40%	40%	50%	60%	70%	86%	90%	90%	92%
Diesel APUs	10%	10%	10%	25%	25%	35%	34%	21%	14%	12%
Battery APUs	0%	0%	0%	0%	0%	0%	7%	10%	8%	11%
Battery APUs with plug in capability	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Truck Stop Electrification Capable	0%	0%	0%	0%	0%	0%	10%	10%	10%	10%
Practices										
Limit Speed	85%	85%	85%	85%	85%	90%	90%	90%	90%	90%
Reduce empty miles (back-hauls, routing, etc)	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Driver training for fuel economy	85%	85%	85%	85%	85%	85%	85%	90%	90%	90%
In cab notfication of behaviors	50%	50%	50%	50%	50%	50%	50%	50%	50%	60%
Routing optimization	75%	75%	75%	75%	85%	85%	85%	85%	85%	80%

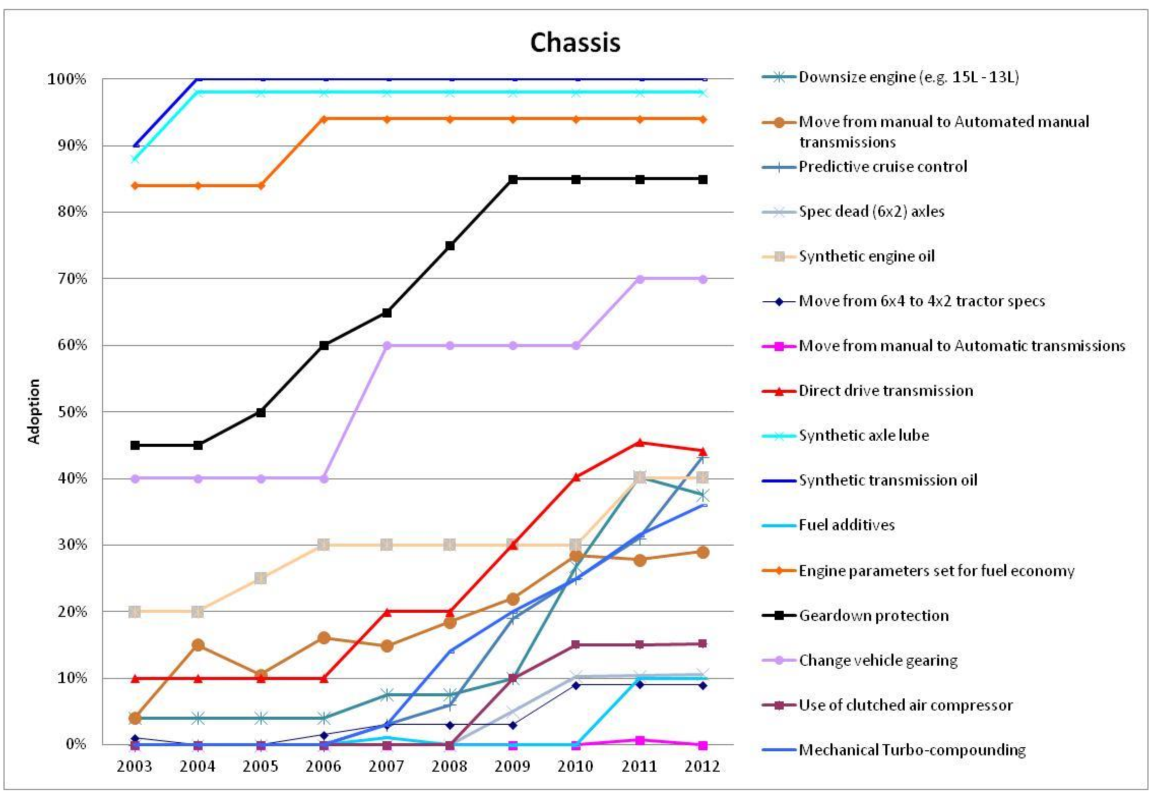
Appendix C: Technology Adoption Curves



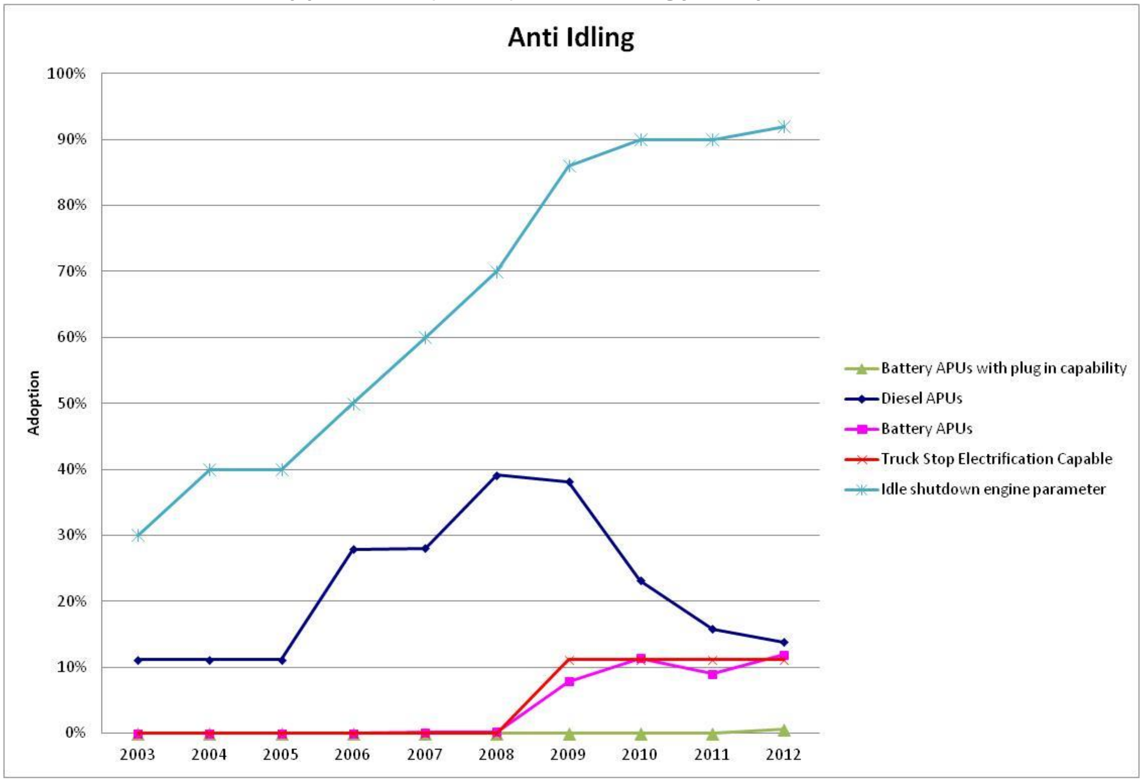


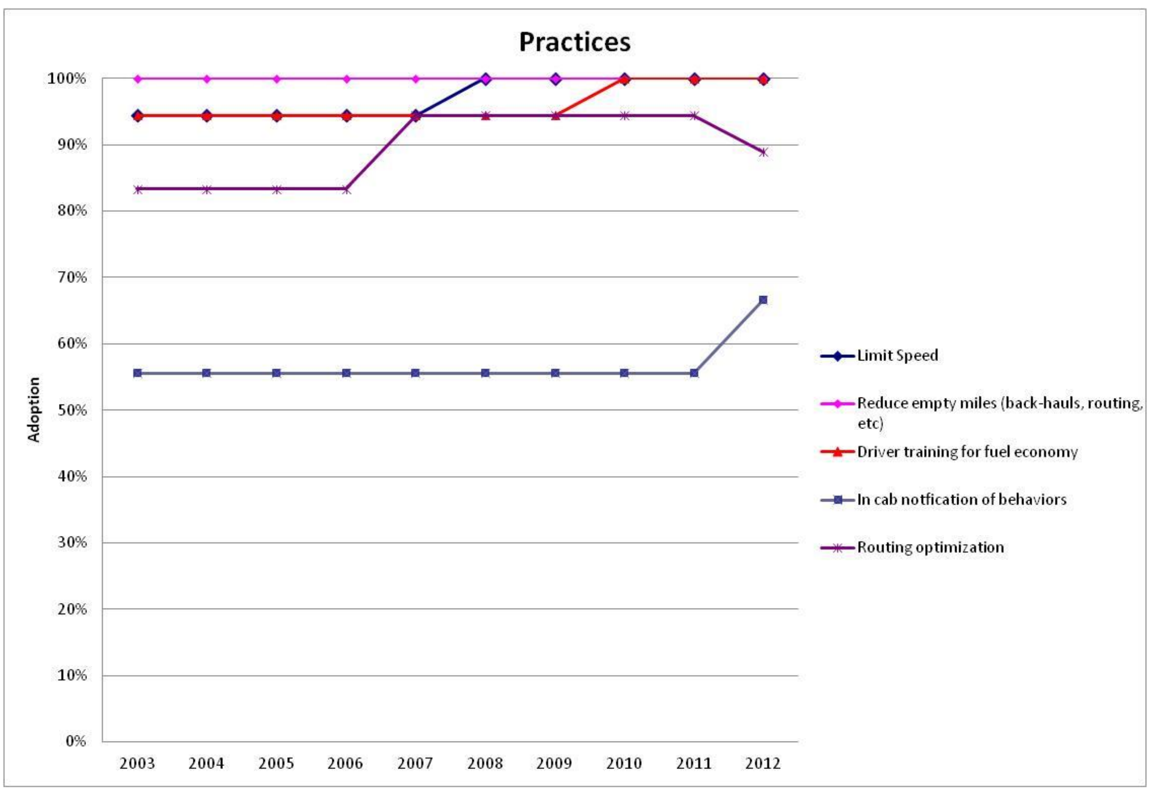
Appendix C (Cont.): Technology Adoption Curves





Appendix C (Cont.): Technology Adoption Curves





Appendix D: Technology Adoption by Fleet

Technologies / Fleets	A	B	C	D	E	F	G	H	I	J
Reduce empty miles (back-hauls, routing, etc)	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Synthetic transmission oil	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Limit Speed	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Synthetic axle lube	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Full height roof air fairing	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Driver training for fuel economy	Slow ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Fast ramp to 100%
Aerodynamic Tractors (ie no external air cleaners, long and tall hood, etc.)	Slow ramp to 100%	Fast ramp to 100%	Slow ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Slow ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Cab Extenders	Slow ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Aerodynamic mirrors	Fast ramp to 100%	Fast ramp to 100%	Slow ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Slow ramp to 100%	Slow ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Engine parameters set for fuel economy	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Routing optimization	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Fast ramp to 100%
Minimize 5th wheel height	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Aerodynamic bumpers	Slow ramp to 100%	Fast ramp to 100%	Slow ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Slow ramp to 100%	Fast ramp to 100%	Slow ramp to 100%	Fast ramp to 100%
Aluminum wheels tractors	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Fast ramp to 100%
Geardown protection	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Ramping at <100%	Never purchased	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Idle shutdown engine parameter	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
In cab notfication of behaviors	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Never purchased	Fast ramp to 100%	Never purchased	Fast ramp to 100%	Never purchased	Never purchased
Change vehicle gearing	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Never purchased	Fast ramp to 100%	Never purchased
Remove parts - bug deflectors, etc.	Ramping at <100%	Fast ramp to 100%	Never purchased	Fast ramp to 100%	Never purchased	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Slow ramp to 100%
Tractor chassis skirts - full	Never purchased	Fast ramp to 100%	Slow ramp to 100%	Fast ramp to 100%	Ramping at <100%	Slow ramp to 100%	Slow ramp to 100%	Fast ramp to 100%	Never purchased	Never purchased
Low rolling resistance duals (Smartway)	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%
Specified weight reduction on trailers	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Fast ramp to 100%	Never purchased	Fast ramp to 100%	Never purchased	Fast ramp to 100%
Fixed 5th wheel w/ minimum gap	Never purchased	Started and stopped	Never purchased	Fast ramp to 100%	Never purchased	Ramping at <100%	Slow ramp to 100%	Never purchased	Fast ramp to 100%	Fast ramp to 100%
Aluminum wheels trailers	Fast ramp to 100%	Never purchased	Ramping at <100%	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Never purchased	Fast ramp to 100%
Specified weight reduction on tractors	Never purchased	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Never purchased	Never purchased	Fast ramp to 100%
Tractor chassis skirts - partial	Never purchased	Started and stopped	Slow ramp to 100%	Fast ramp to 100%	Ramping at <100%	Slow ramp to 100%	Slow ramp to 100%	Never purchased	Never purchased	Started and stopped
Direct drive transmission	Fast ramp to 100%	Fast ramp to 100%	Never purchased	Fast ramp to 100%	Ramping at <100%	Ramping at <100%	Never purchased	Never purchased	Fast ramp to 100%	Never purchased
Trailer skirts	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Started and stopped	Ramping at <100%	Fast ramp to 100%	Fast ramp to 100%	Fast ramp to 100%	Ramping at <100%	Slow ramp to 100%
Synthetic engine oil	Never purchased	Fast ramp to 100%	Ramping at <100%	Never purchased	Never purchased	Ramping at <100%	Never purchased	Fast ramp to 100%	Never purchased	Fast ramp to 100%
Diesel APUs	Never purchased	Never purchased	Started and stopped	Never purchased	Ramping at <100%	Started and stopped	Never purchased	Fast ramp to 100%	Never purchased	Started and stopped
Remove parts - fender mirrors?	Never purchased	Fast ramp to 100%	Never purchased	Started and stopped	Ramping at <100%	Started and stopped	Never purchased	Never purchased	Never purchased	Never purchased
Move from manual to Automated Manual transmissions	Slow ramp to 100%	Started and stopped	Never purchased	Started and stopped	Ramping at <100%	Ramping at <100%	Ramping at <100%	Never purchased	Never purchased	Ramping at <100%
Use of doubles or triples trailers	Ramping at <100%	Ramping at <100%	Never purchased	Never purchased	Never purchased	Fast ramp to 100%	Never purchased	Never purchased	Fast ramp to 100%	Ramping at <100%
Cutdown mudflap width	Never purchased	Fast ramp to 100%	Ramping at <100%	Fast ramp to 100%	Never purchased	Never purchased	Never purchased	Never purchased	Never purchased	Never purchased
Tire pressure inflation - trailer	Ramping at <100%	Ramping at <100%	Fast ramp to 100%	Never purchased	Ramping at <100%	Never purchased	Never purchased	Fast ramp to 100%	Never purchased	Slow ramp to 100%

(dark green)	Fast ramp to 100%
(light green)	Slow ramp to 100%
(yellow)	Ramping at <100%
(red)	Started and stopped
(white)	Never purchased

Appendix D (Cont.): Technology Adoption by Fleet

Technologies / Fleets	A	B	C	D	E	F	G	H	I	J
Downsize engine (e.g. 15L - 13L)										
Wide based tires - tractors										
Mechanical Turbo-compounding										
Predictive cruise control										
Wide based tires - trailers										
Flyswatter mudflaps - trailer										
Flyswatter mudflaps - tractor										
Use of clutched air compressor										
Truck Stop Electrification Capable										
Remove or relocate any trailer drag parts? (name them)										
Battery APUs										
Move from 6x4 to 4x2 tractor specs										
Spec dead (6x2) axles										
Tire pressure monitoring - trailer										
Wheel covers - tractors										
Fuel additives										
Trailer nose cones										
Trailer undertray or bogie fairing										
Boat tails										
Tire pressure monitoring - tractor										
Move from manual to Automatic transmissions										
Battery APUs with plug in capability										
Wheel covers - trailers										
Vortex generators										
Tires filled using Nitrogen										

	Fast ramp to 100%
	Slow ramp to 100%
	Ramping at <100%
	Started and stopped
	Never purchased