NACFE

NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

2022 Annual FLEET FUEL Study

PARTICIPATING FLEETS

NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

ANNUAL FLEET FUEL STUDY

*REAL FLEETS. **REAL EXPERIENCE.***

CFI
C.R. ENGLAND
FRITO-LAY
J.B. HUNT
MAVERICK TRANSPORTATION
MESILLA VALLEY TRANSPORTATION
NFI
NUSSBAUM TRANSPORTATION
PAPER TRANSPORT
PILOT FLYING J
PITT OHIO
SCHNEIDER
UPS
U.S. XPRESS
WERNER ENTERPRISES

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2022 FISCAL SUPPORT

Platinum

Gold

Silver

Bronze

Philanthropy

Report published December 13, 2022

ABOUT US

NACFE
NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

ABOUT NACFE

The North American Council for Freight Efficiency (NACFE) works to drive the development and adoption of efficiency enhancing, environmentally beneficial, and cost-effective technologies, services, and operational practices in the movement of goods across North America. NACFE provides independent, unbiased research, including Confidence Reports on available technologies and Guidance Reports on emerging ones, which highlight the benefits and consequences of each, and deliver decision-making tools for fleets, manufacturers, and others. NACFE partners with RMI on a variety of projects including the Run on Less demonstration series, electric trucks, emissions reductions, and low-carbon supply chains. Visit NACFE.org or follow us on Twitter @NACFE_Freight.

RUN ON LESS

ABOUT RUN ON LESS BY NACFE

Run on Less 2017 was a first-of-its-kind fuel efficiency roadshow that proved 10 MPG is possible with various combinations of commercially available technologies. Seven participating fleets hauled real freight on real routes during the three-week run across North America.

Run on Less Regional was conducted in October of 2019. Ten participating fleets demonstrated a variety of commercially available freight efficiency technologies in the three-week cross-country roadshow, proving that 8.3. MPG is possible in regional haul.

Run on Less – Electric was the first NACFE demonstration to focus on electric vehicles. Thirteen fleet-OEM pairs in the US and Canada participated in the three-week long event. If all US and Canadian medium- and heavy-duty trucks in the market segments — vans and step vans, medium-duty box trucks, terminal tractors and heavy-duty regional haul — studied in the Run became electric, about 100 million metric tons of CO_2 would be saved from entering the atmosphere. Visit runonless.com or follow us on Twitter @RunOnLess.

GET INVOLVED

NACFE could use the assistance of fleets, manufacturers and other trucking industry stakeholders in improving freight efficiency. Become a part of this exciting opportunity.

Learn more at www.nacfe.org or contact Mike Roeth at mike.roeth@nacfe.org

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The Annual Fleet Fuel Study (AFFS) contains the results of a deep-dive investigation into the adoption of various products and practices for improving freight efficiency among 24 major North American fleets. Fleets share with North American Council for Freight Efficiecny (NACFE) their purchase and use of 86 technologies going back to 2003.

By this report, completed in 2022, NACFE has accumulated data on the purchasing habits of 24 fleets. To be included in this data set, fleets provided data on the tractors and trailers for which they specified the features (technologies) and purchased the fuel for the tractors. This makes for a clean data set for comparing the fuel efficiency to the adoption decisions.

The fleets have been very consistent in providing data for this report, but over the years, some fleets continue to participate, others elect not to and are replaced by others. NACFE keeps each fleet's data in the data set and makes note where any particulate fleet's participation or lack thereof affected the results in a meaningful way. For 2022, 15 fleets provided data for their 2019, 2020 and 2021 operations. In total, 24 fleets have provided data over the 11 years of the study.

NACFE would like to thank the participating fleets for offering such important information to the rest of the industry. This study provides a benchmarking opportunity for participating fleets to continue to improve their operations and increase freight efficiency. If you are interested in joining this study, please contact NACFE at mike.roeth@nacfe.org. For other fleets the details in this study will provide a roadmap for your consideration of technologies and practices to help reduce fuel costs.

ACKNOWLEDGMENTS

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NACFE
NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

2022 FISCAL SUPPORT

Platinum

Shell

Gold

Pilot, Flying J, Lubrizol, Eaton (Powering Business Worldwide), Schneider, Navistar, Dana, Meritor (Run with the Bull), UPS, Michelin, Freightliner, PepsiCo, Ideanomics (Digitizing Tomorrow), Lion Electric, Black & Veatch, bp pulse, Penske, Goodyear

Silver

Cummins, P.S.I. Pressure Systems International, NRECA (America's Electric Cooperatives), Kenworth Sales, Great Dane, Geotab, Nikola, Volvo, Peterbilt, Orange EV

Bronze

Allison Transmission, BASF (We create chemistry), trucklabs (Engineering the Road Ahead), Stoughton, The Aluminum Association, Hendrickson, Romeo Power

Philanthropy

William + Flora Hewlett Foundation, ClimateWorks Foundation, Catena Foundation

"The goal of NACFE's Annual Fleet Fuel Study is to increase the adoption of fuel saving technologies across the trucking industry."

— Mike Reoth, executive director, NACFE

ANNUAL FLEET FUEL STUDY

About NACFE's Annual Fleet Fuel Study

This is the ninth update of the North American Council for Freight Efficiency's (NACFE) 2012 inaugural study that has been described as an important read for anyone working in this area. Fifteen fleets have supplied data for this 2022 report. NACFE paused the study for three years given industry attention to an extraordinary set of circumstances, most significantly the COVID-19 pandemic. This report incorporates technology adoption and efficiency that now includes data from 2019, 2020 and 2021.

"While it made sense for NACFE to delay gathering data for this report, I am excited it's back because it is an important tool for fleets that are looking to operate in a more fuel-efficient manner. I look forward to this report and read it each year within days of it being published. It is important to Schneider's efforts, and it can be a critical resource to any fleet or owner/operator as well as manufacturers and others who are working to improve Class 8 efficiency," offers Rob Reich, chief administrative officer, Schneider.

The findings of this report should prove invaluable to efforts both to improve the fuel economy of a fleet and to develop and deliver fuel efficiency products to the marketplace.

The scope of this work encompassed Class 8 tractors (day cabs and sleepers) and trailers in regional and long-haul applications. Fleets providing data for this 2022 study include:

CFI
C.R. ENGLAND
FRITO-LAY
J.B. HUNT
MAVERICK TRANSPORTATION
MESILLA VALLEY TRANSPORTATION
NFI
NUSSBAUM TRANSPORTATION
PAPER TRANSPORT
PILOT FLYING J
PITT OHIO
SCHNEIDER
UPS
U.S. XPRESS
WERNER ENTERPRISES

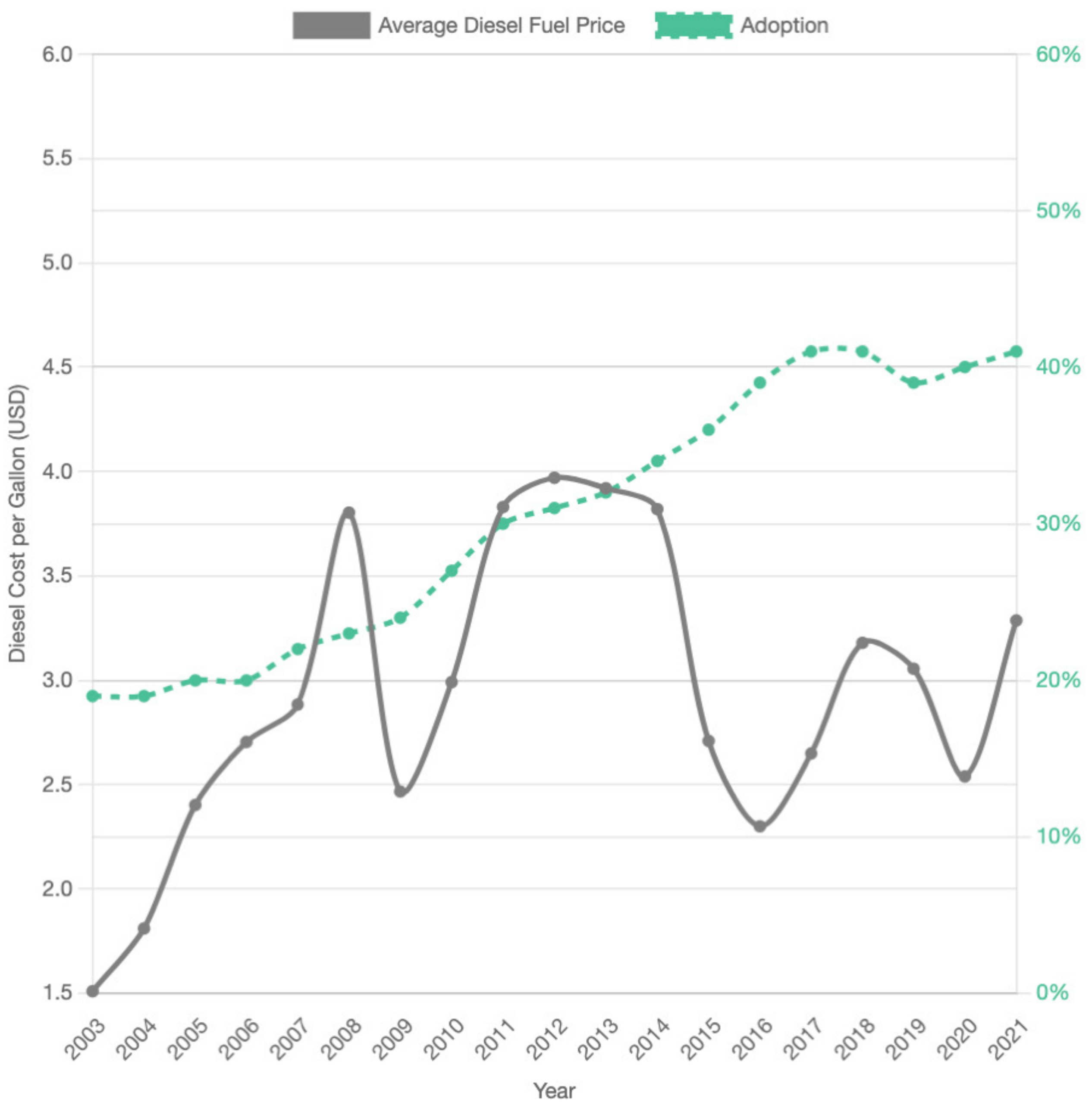
The primary goal of the report is to study the fleets' levels of adoption of 86 technologies and practices, and the savings those drove in each organization. All 86 technologies are currently available and not prototypes, validation test units, or pre-production units. This study focuses on technologies purchased and implemented onto a fleet's trucks and trailers. In certain cases, fleets were asked if they had retrofitted any of the devices on their equipment, but this was done for context and is not included in the adoption data.

Report Findings

The primary finding of this report is that the 15 fleets studied are increasing their rate of adoption of these technologies, and that they are enjoying improved fuel economy as a result. The overall adoption rate for the technologies studied in this report has grown from 17% in 2003 to 41% in 2021. Not all technologies could be applied to a single tractor-trailer, as some are clearly an either/or decision. 2021 showed an increase in fuel cost at the pump with diesel fuel, which powers a large majority of this fleet, averaging $3.29 per gallon for 2021 (EIA, 2022), up from $2.54 in 2020. This is a 30% increase year over year and a $0.99 per gallon increase from 2016 (when fuel prices were at their lowest since 2004). The five-year average is $2.94, meaning that fuel costs annualized in 2021 were within $0.34 of that level (See Figure ES1).

FIGURE ES1

PRICE OF DIESEL AND NACFE FLEETS ADOPTION



The average fleet-wide fuel economy of the trucks in this study was 7.23 mpg in 2021 — a slight increase from the 7.15 in 2017. There is variability in each fleet's yearly fuel efficiency depending on many factors, but overall, these fleets had a very impressive average annual rate of improvement in MPG of 2.0% from 2011 to 2017.

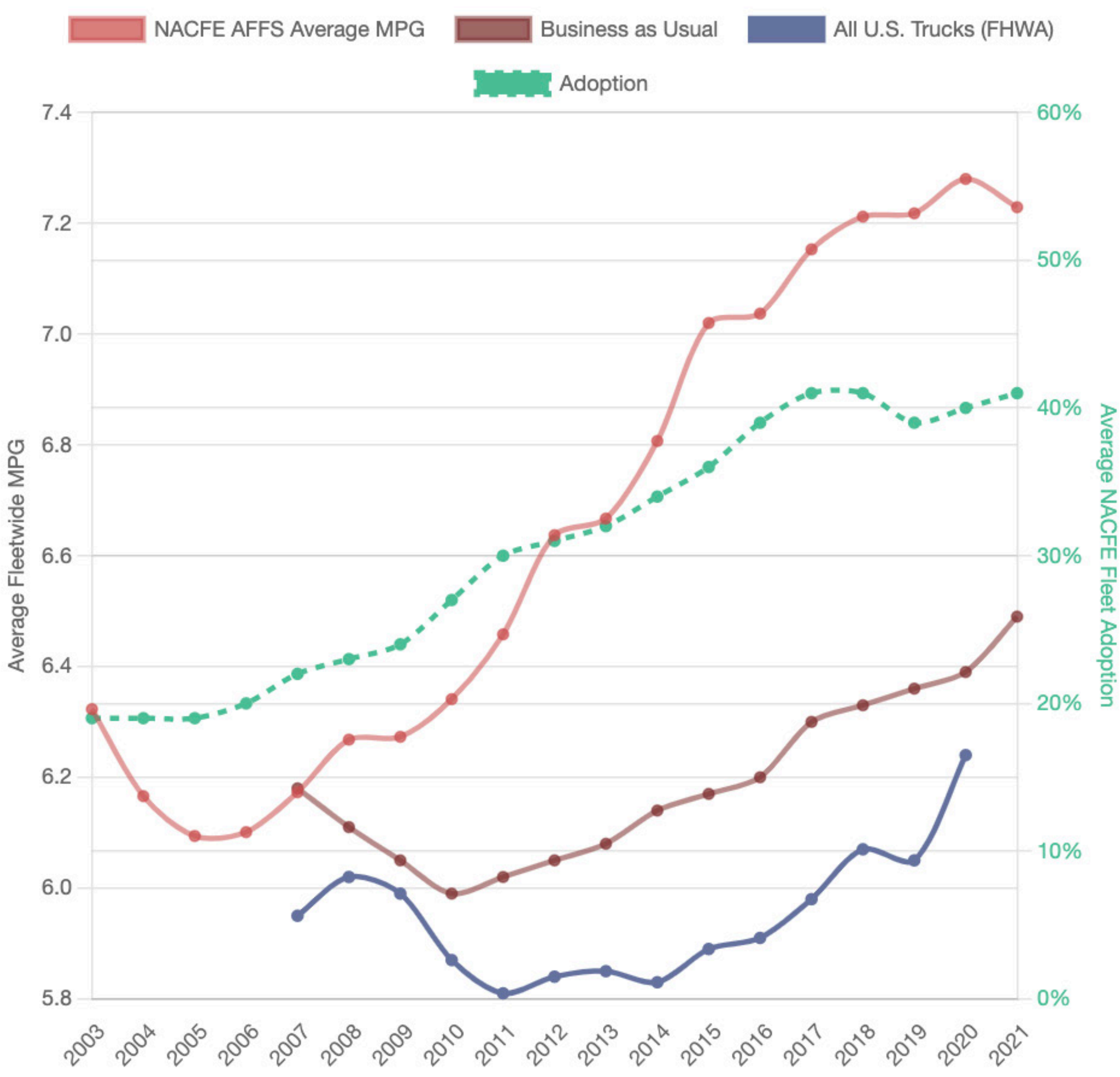
Figure ES2 shows the average fleet-wide fuel economy for the combined population of trucks in this study compared to the overall U.S. truck population. A business-as-usual (BAU) line is included for comparison. The BAU shows a projection of what average MPG might have been given the combined impact of 2002, 2007, and 2010 emission regulations, and the effect of the 2014 and 2017 Greenhouse Gas (GHG) base powertrain improvements. In other words, this suggests the level of efficiency had the 15 fleets not purchased the technologies that are available to them as options.

The national average for the approximately 1.7 million tractors in over-the-road use is shown and was obtained using International Fuel Tax Reporting data from the Federal Highway Administration (FHWA, 2019). Of note this year is that the national average of these trucks jumped to 6.24 MPG in 2020, a reflection of the fact that the MPG increases over the last 10 years are starting to be reflected in the overall population's efficiency. As of the finalization of this report, 2021 data was not yet available.

During NACFE's Run on Less demonstration in September of 2017, the tractor-trailers equipped with the best of the best currently available technologies attained 10.1 MPG.

FIGURE ES2

AVERAGE FLEET-WIDE FUEL ECONOMY OVER TIME



METHODOLOGY

This report's conclusions were generated through input provided by a total of 24 fleets beginning in 2012. Fleets were asked to fill out a questionnaire about their use of 86 fuel-efficiency technologies and practices for their tractors and trailers.

Over the course of the years of the study, some fleets have dropped out, while others have been added. For the 2022 study, 15 fleets provided data covering their 2019, 2020 and 2021 operations.

And in October 2019, the group conducted a second Run on Less where the average for the more demanding regional haul duty cycles reached 8.3 MPG.

The fuel savings in 2021 between the BAU of 6.49 MPG and the NACFE fleets' average of 7.23 MPG amounts to $5,178 per year per truck, at the $3.29 per gallon fuel cost over the average tractor mileage of 100,000. The fleets are saving $7,207 over the national average of 6.24 MPG. If fuel costs had been at the five-year average of $2.94 per gallon, the savings would have been $4,635 and $6,452, respectively. And finally, the 15 fleets operating 75,000 trucks saved over $540,000 in 2021 compared to the average trucks on the road.

Results Reflect Growth of Technology Use

The results of the AFFS clearly reflect a growing use of fuel-saving technologies and practices and 2022 provided another interesting set of data. Following are the high-level conclusions reached by the study team this year.

Study fleet-wide fuel efficiency stalled from 2018 to 2021. After an average year-over-year increase of 2% from 2011 through 2017, fleet-wide average from these benchmark fleets was flat at 7.24 MPG from 2018 through 2021. NACFE received input from the participating fleets and other fleets, OEMs and manufacturers as well as other groups and determined this was caused by the following factors:

- Many fleets have increased their cruise and pedal highway speeds. In fact, fleets with maximum speed limiters under 65 MPH have declined from 80% in 2016 to 62% in 2021. This results in a significant increase in fuel consumption with a 0.1 MPG hit for every 1 MPH increase in average speed.
  - Fleets have been keeping trucks longer, but truck builders have been bringing better MPG trucks to the market each model year. This decreases the number of new more fuel efficient trucks in the study.
  - GHG phase 2 regulations have required manufacturers to bring improved base engine and truck MPG, particularly in 2017 and 2021 when compliance steps were required. But, the fleets in the study have slightly decreased their adoption of optional fuel-efficiency features.
  - Anecdotally several fleets have told NACFE that their idle times have increased in recent years. Drivers spent more time in their bunks or waiting at shipper's and receiver's docks. This, combined with a reduction in the adoption of battery HVACs and diesel APUs contribute to an overall decline in MPG.

"Improving fuel economy doesn't always grab the headlines, but it adds up to real results. Cummins estimates that the 100,000 internal combustion engines that are each 10% more efficient are equivalent to the improvement gained by putting 10,000 zero-emission vehicles on the road."

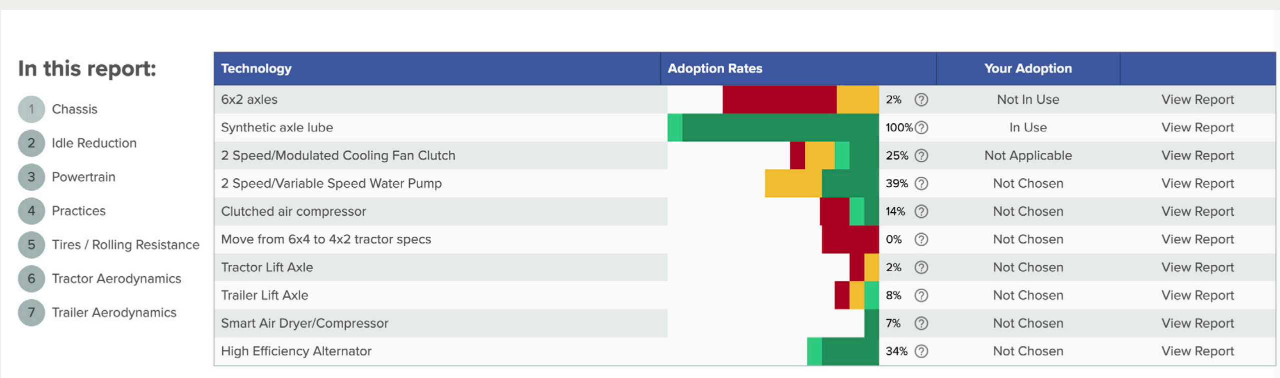
— Jennifer Rumsey, CEO, Cummins, Inc.

- A few new fleets with lower levels of aerodynamics adoption replaced some other fleets that had higher adoption rates and efficiency. This was a function of the fact that some regional haul fleets replaced long-haul fleets in this year's AFFS and traditionally regional fleets install fewer aerodynamic devices.
- All heavy-duty tractors in the United States have improved efficiency in the past few years. For all Class 8 tractor-trailers, the national MPG average has increased rather sharply in the last three years from 5.98 MPG to 6.24 MPG. As the higher MPG delivered by model year 2010 to 2018 trucks have found their way into replacing older trucks, the average is increasing. Tractor life is generally in the 10 to 15 year range, so trucks being bought in the five-year replacement cycle can have an MPG increase of one to two MPG.

- Sustainability has become a large driver for fleets to decarbonize the way they move goods. Corporations are responding to an increased demand by their shipping customers and the general public to move goods more sustainably. The industry is not waiting for zero-emission solutions to do this, as improving freight efficiency on diesel tractor-trailers is a key decarbonization strategy that saves emissions now. Decarbonization does not mean only a move to zero-emissions freight movement. Improving MPG of diesel tractors and trailers with these technologies is a clear effort to burn less fuel and reduce carbon emissions.
- Regulations will drive freight efficiency through the next two decades. The GHG phase 2 regulations have steps for the OEMs to comply with in Model Years 2024 and 2027 and a GHG phase 3 is being studied by the EPA and NHTSA, for implementation next decade. These are significant MPG improvements that will have OEMs develop, offer and sell new features on their tractors and trailers that will show up in this study in future years.

NEW BENCHMARKING TOOL

New for the Annual Fleet Fuel Study (AFFS) for 2022 is an online version of the technology benchmarking tool. Users have the ability to complete their benchmarking online for each technology category in which they are interested or for all 86 technologies. They then receive a customized interactive report report which includes the user's responses prioritized by the technologies that have the greatest gap between the user and the average of the AFFS fleets. By using the interactive tool, fleets also contribute to the growing database of technology adoption data. There is no cost to use this tool.


In this report:

1 Chassis
2 Idle Reduction
3 Powertrain
4 Practices
5 Tires / Rolling Resistance
6 Tractor Aerodynamics
7 Trailer Aerodynamics

Technology	Adoption Rates	Your Adoption	
6x2 axles	2%	Not In Use	View Report
Synthetic axle lube	100%	In Use	View Report
2 Speed/Modulated Cooling Fan Clutch	25%	Not Applicable	View Report
2 Speed/Variable Speed Water Pump	39%	Not Chosen	View Report
Clutched air compressor	14%	Not Chosen	View Report
Move from 6x4 to 4x2 tractor specs	0%	Not Chosen	View Report
Tractor Lift Axle	2%	Not Chosen	View Report
Trailer Lift Axle	8%	Not Chosen	View Report
Smart Air Dryer/Compressor	7%	Not Chosen	View Report
High Efficiency Alternator	34%	Not Chosen	View Report

The interactive benchmarking tool replaces the previous Excel-based version. Each technology, grouped by category, is listed with the average adoption rate for all fleets in the most recent survey and a color bar indicating the proportion of fleets that have explored the technology and the rate at which they have adopted it. A technology which has the color bar completely filled in has been explored by all fleets in the survey. An all green bar indicates that all fleets that have explored the technology have adopted it in 100% of their new trucks. A technology which is showing a wide red bar would indicate that many fleets have explored the technology but have stopped using it. Some technologies have some green and some red in the adoption rate bar, which could indicate that the technology is suitable to some applications or duty cycles and not others.

WEBSITE UPDATES

In conjunction with the release of the Annual Fleet Fuel Study (AFFS), NACFE is updating its website. NACFE has issued Confidence Reports on nearly all of the 86 technologies in the AFFS. The website has been updated to more closely link the AFFS to the Confidence Reports where fleets can find more in-depth information on a technology they are considering adopting based on what they learned in the AFFS.

Recommendations

Our goal is for the information shared in this study to provide other fleets a roadmap for navigating the many available technologies that can have a positive impact on lowering fuel expenses. A benchmarking tool is being released with this study that can be used by any truck owner to compare his or her own technology adoption to that of the fleets in this study. Also, technology developers and manufacturers can use this data to improve the total cost of ownership of their products. The package of information released includes this full report, a full set of graphics, and the data set and benchmarking tool. We expect it will be helpful in your efforts.

Here are some recommendations to help fleets operate more efficiently.

1. Collect and monitor fuel consumption by vehicle. Fleet MPG improves vehicle by vehicle. Tracking fuel consumption by vehicle also allows a fleet to understand which duty cycles and applications are best for fuel efficiency, identify pieces of equipment that need to be maintained or replaced and reward or re-train drivers that may be over- or under-performing.
   - Set long-term MPG improvement goals. Many fuel-saving technologies have a high return on investment which will improve the profitability of a fleet.
   - Use the Annual Fleet Fuel Study benchmarking tool to identify technologies to test.
   - Continuously track your progress
2. Commit to and budget for an ongoing plan of MPG improvement.
3. If possible, develop a test route and test driver with which to test new technologies. This can be a purpose-made route or an ongoing dedicated route where MPGs are fairly consistent.
4. If purchasing used equipment, purchase equipment from fleets known for having good fuel economy. These fleets are continually testing technologies and are adopting ones that are successful.
5. Allow for failure. Not all technologies will be right for your application and duty cycle. Do not let short-term failures derail your long-term goals.

Improving your efficiency through adoption of these technologies will improve the range when you decide to move forward with alternative fueled powertrains such as battery electric.

“While it made sense for NACFE to delay gathering data for this report, I am excited it’s back because it is an important tool for fleets that are looking to operate in a more fuel-efficient manner.”

— Rob Reich, chief adminitrative officer, Schneider

1 INTRODUCTION

This report covers the findings of the North American Council for Freight Efficiency's (NACFE) Annual Fleet Fuel Study (AFFS). For 11 years, NACFE has studied the adoption rate of 86 technologies that improve freight efficiency. The AFFS provides real-world insight on what fleets are doing to get more miles from a gallon of diesel fuel and is based on the premise that regardless of the cost, fuel represents a significant portion of a fleet's total operating costs.

The current price of diesel — $5.317 per gallon as of October 31, 2022 [17] — means that even small improvements in fuel economy can result in large gains.

This report provides trucking industry background, explains the methodology used to calculate adoption rates, provides technology adoption curves and shares overall fuel savings from the adoption of technologies.

1.1 Overview

NACFE (www.nacfe.org) works to drive the development and adoption of efficiency enhancing, environmentally beneficial, and cost-effective technologies, services, and operational practices in the movement of goods across North America. NACFE provides independent, unbiased research, including Confidence Reports on available technologies and Guidance Reports on emerging ones, which highlight the benefits and consequences of each, and deliver decision-making tools for fleets, manufacturers, and others. NACFE partners with RMI on a variety of projects including the Run on Less demonstration series, electric trucks, emissions reductions, and low-carbon supply chains.

NACFE also holds workshops to openly debate their findings and recommendations. Success for NACFE will be measured in the accelerated adoption of technologies and practices that promote freight efficiency. See Figure 1.

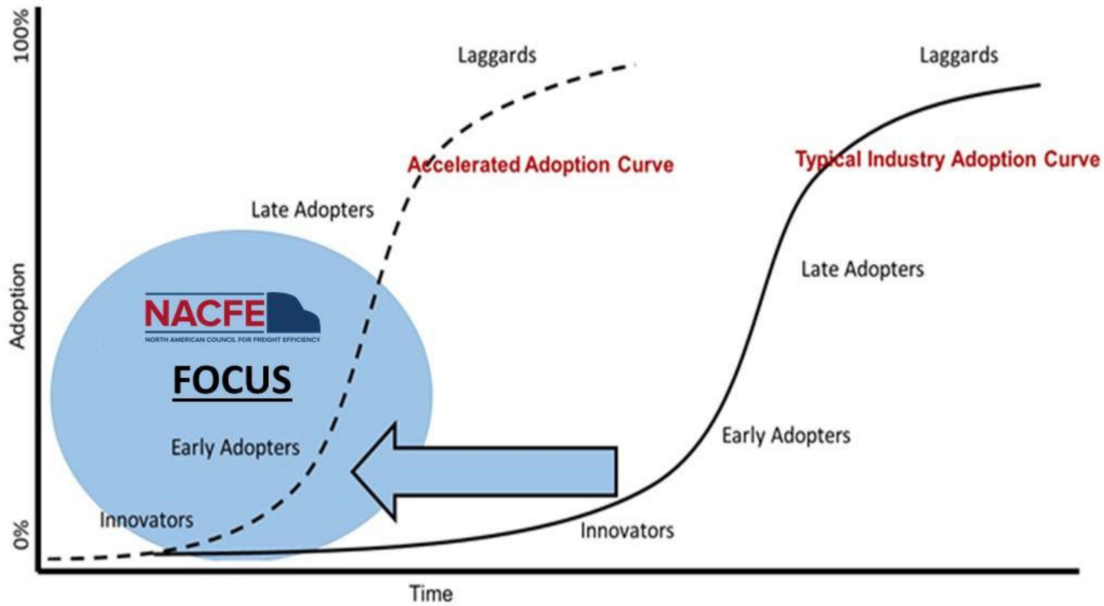


Figure 1: NACFE Approach to Accelerating Adoption

NACFE in partnership with RMI, has conducted three cross-country demonstrations to showcase advancements in fuel efficiency. One focused on long haul routes in September 2017, a second in 2019 on regional haul and the third in 2021 focused on battery electric vehicles. There is much to be learned from the drivers, the fleets, manufacturers and from the data accumulated during the Runs. All can be reviewed at www.runonless.com.

1.2 Background

The fuel costs faced by the trucking industry are a significant part of the expense to operate a tractor-trailer in North America. According to the 2021 American Transportation Research Institute's (ATRI) report on the Operating Costs of Trucking, fuel has been as high as $0.65 per mile driven occurring in 2013 and then dropped to $0.34 and $0.31 by 2016 and 2020, respectively. [3] But throughout 2021, the price per gallon for diesel skyrocketed to an all-time high of $5.81 on June 20, 2022. [3]. See Figure 2. For a point of reference, using a cost of even $5.00 per gallon and 7 MPG driven over an annual amount of 100,000 miles, the cost to fuel one tractor-trailer for a year would be more than $70,000. A new tractor might cost $150,000, so that tractor will spend in fuel the complete cost of the tractor in its first two years of use.

Motor Carrier Costs	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Vehicle-based										
Fuel Costs	$0.641	$0.645	$0.583	$0.403	$0.336	$0.368	$0.433	$0.384	$0.308	$0.417
Truck/Trailer Lease or Purchase Payments	$0.174	$0.163	$0.215	$0.230	$0.255	$0.264	$0.265	$0.256	$0.271	$0.279
Repair & Maintenance	$0.138	$0.148	$0.158	$0.156	$0.166	$0.167	$0.171	$0.149	$0.148	$0.175
Truck Insurance Premiums	$0.063	$0.064	$0.071	$0.074	$0.075	$0.075	$0.084	$0.071	$0.087	$0.086
Permits & Licenses	$0.022	$0.026	$0.019	$0.019	$0.022	$0.023	$0.024	$0.020	$0.016	$0.016
Tires	$0.044	$0.041	$0.044	$0.043	$0.035	$0.038	$0.038	$0.039	$0.043	$0.041
Tolls	$0.019	$0.019	$0.023	$0.020	$0.024	$0.027	$0.030	$0.035	$0.037	$0.032
Driver-based										
Driver Wages	$0.417	$0.440	$0.462	$0.499	$0.523	$0.557	$0.596	$0.554	$0.566	$0.627
Driver Benefits	$0.116	$0.129	$0.129	$0.131	$0.155	$0.172	$0.180	$0.190	$0.171	$0.182
TOTAL	**$1.633**	**$1.676**	**$1.703**	**$1.575**	**$1.592**	**$1.691**	**$1.821**	**$1.699**	**$1.646**	**$1.855**

Figure 2: Average Marginal Costs Per Mile 2011-2021 (ATRI)

In parallel, the United States Environmental Protection Agency (US EPA) and the National Highway Traffic Safety Administration (NHTSA) have enacted greenhouse gas (GHG) emissions regulations on commercial vehicles extended to 2030 that require manufacturers to develop and sell technologies to improve efficiency. [11] These factors have driven fleets, manufacturers, and others to improve the efficiency of over-the-road tractor-trailers.

Fortunately, myriad technologies that can cost-effectively improve the fuel efficiency of Class 8 trucks are readily available on the market today. Unfortunately, multiple barriers have stymied industry adoption of such technologies, including a lack of data about the true performance gains these technologies offer, and a lack of confidence in the payback for investment in these technologies. To overcome those barriers and facilitate the industry's trust in and adoption of the most promising cleaner operating technologies, NACFE produces a series of Confidence Reports.

Figure 3 shows 25 years of the price of diesel fuel in the United States. [4] These years can be categorized in terms of five time periods.

1. 1994 (and even back to the mid-70s) to 2004, where fuel cost less than $1.75 per gallon;
2. 2004 to 2009 when, except for a short correction in 2009, fuel costs generally rose to around $4 per gallon;
3. 2011 to the end of 2014, with fuel costs very consistently at about $4 per gallon;
4. 2015 to 2020 saw a drop in fuel prices to around $2.50 for five years;
5. And finally, a run-up in fuel prices to a record high of $5.81 in June 2022.

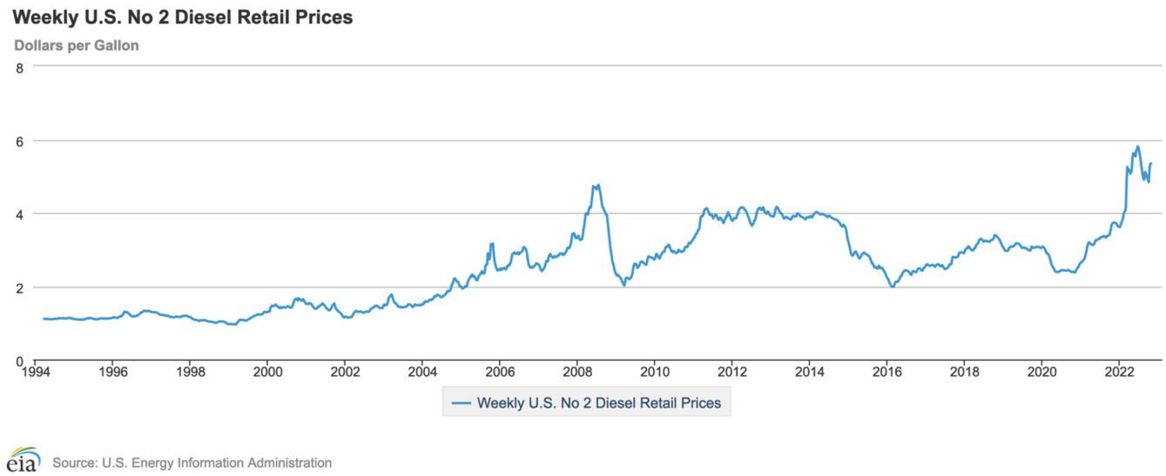


Figure 3: U.S. Annual Diesel Fuel Prices

No one knows for sure what the price of fuel will be in the future, but fleets should conduct sensitivity analyses with respect to fuel prices and expectations about the ownership life of their assets. 2022 brought concerns of higher fuel prices well into the future. Realities of the COVID-19 pandemic, the Russian invasion of Ukraine and other pressures have doubled the cost of fuel to move goods in North America. Regardless of the cost of fuel, it is a very significant operating expense for fleets and needs to be managed.

Investment in proven technologies and practices that allow a truck or fleet to increase its fuel efficiency — meaning that it lets the fleet do the same amount of business while spending less on fuel — is a hugely important option for the industry considering these trends.

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

1.3 NACFE's Annual Fleet Fuel Study

To better understand the history of adoption of fuel-efficiency technologies, in 2011, its second year, NACFE created a methodology for sharing best practices to document and learn from data-driven fleets and provide an early roadmap for the industry on technologies that improve the efficiency of Class 8 tractor-trailers. By this Annual Fleet Fuel Study (AFFS) report, completed in 2022, NACFE has accumulated data on the purchasing habits of 24 fleets. To be included in this dataset, fleets provided data on the tractors and trailers for which they specified the features (technologies) and purchased the fuel for the tractors. This makes for a clean data set for comparing the fuel efficiency to the adoption decisions.

The fleets have been very consistent in providing data for this report, but over the years, some fleets continue to participate, while some elect not to and are replaced by other fleets. NACFE keeps each fleet's data in the data set and makes note where any particular fleet's participation or lack thereof affected the results in a meaningful way. For 2022, 15 fleets provided data for their 2019, 2020 and 2021 operations. In total, 24 fleets have provided data over the 11 years of the study.

The Annual Fleet Fuel study was published annually from 2012 to 2019 and then paused for three years. Given the challenges that fleets and our entire industry had with the pandemic, NACFE decided to delay data acquisition and analysis. In 2022, NACFE reached out to many fleets to get information on their adoption and fuel economy data for these years and this report details their efforts. Figure 4 shows the challenges of moving freight from 2019 through 2021 — the time for which the study was paused. ACT Research created their U.S. Freight Composite to share the favorable or unfavorable business conditions surrounding moving freight.

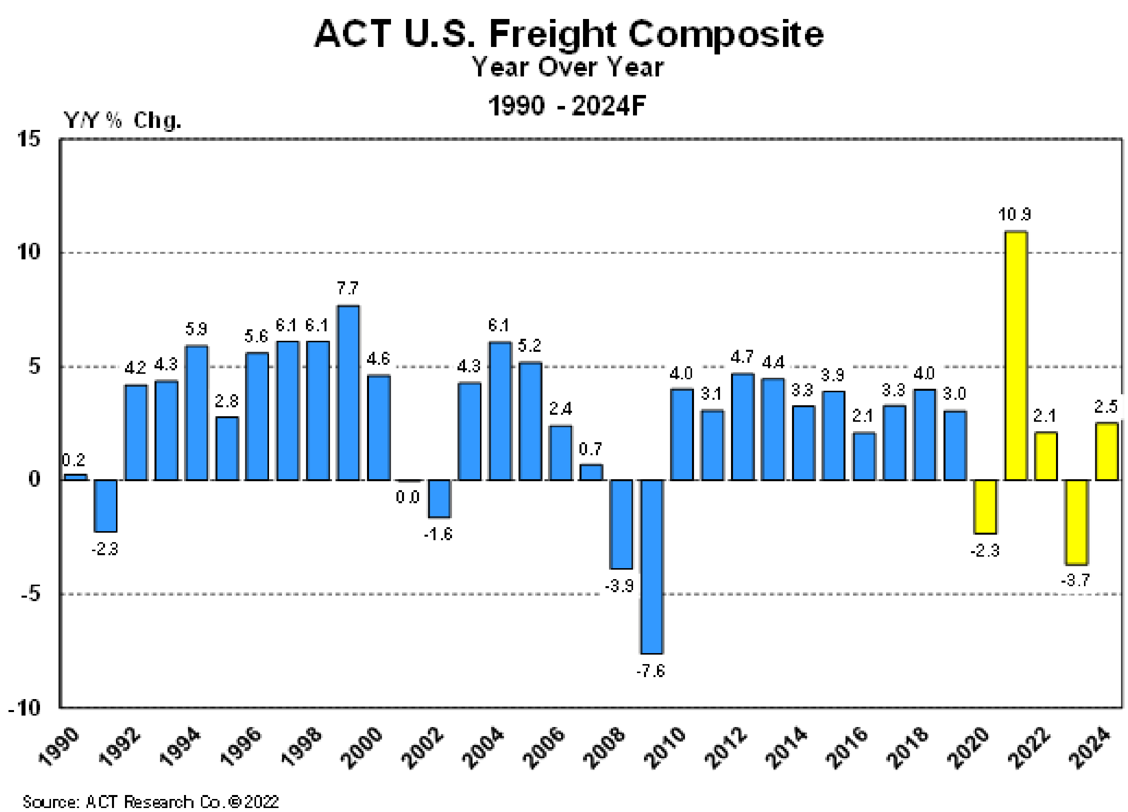


Figure 4: ACT U.S. Freight Composite

Other than the great recession in 2009, the composite showed rather steady and favorable conditions. As we have experienced, the COVID-19 pandemic caused huge disruptions, affecting the entire industry and specifically the fleets in this study. NACFE paused the Annual Fleet Fuel Study for several years in reaction to the pandemic and the changes it brought to the trucking industry. We recognized fleet managers were incredibly busy reacting to pandemic-related market shifts and did not want to add to their workload by asking them to take part in the survey.

Information gathered and shared in this report includes the percent of each fleet's annual purchases that involved any of the 86 currently available technologies for lowering fuel consumption, from 2003 to 2021. A summary of the technology groupings is shown in Figure 5. With 86 technologies, 24 fleets, and 19 years of data, this process provides about 39,000 data points of purchasing behavior on new features by these end users. They also shared their overall fleet-wide fuel efficiency in terms of miles traveled and fuel consumed. It should be noted that one new fleet, J.B. Hunt joined the study this year and given its new data, which extends back to 2003, this year's report is not directly comparable to the last report. Given the addition of new historical data from any new fleet, the past years' totals have all been revised as well.

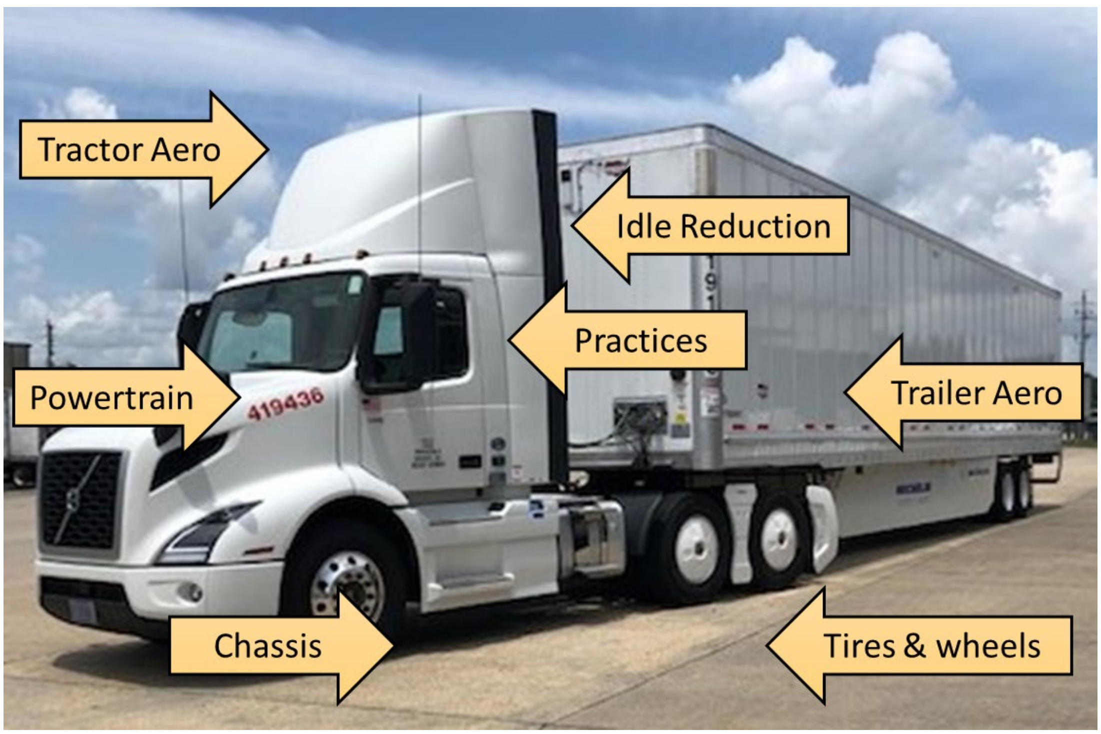


Figure 5: Technologies to Save Fuel (Photo: C&S Wholesale Grocers)

This report distills those data points into adoption curves for all technologies, fleet diversity of adoption, and the associated fleet-wide fuel economy average, for all 19 years in the study period. See all 86 technology adoption curves in Figure 6. Detailed data and figures for all technologies are available in the full set of graphics and the data set and benchmarking tool published along with this report. For the many industry suppliers reading this report, please encourage business development managers and review boards to consider these adoption rates compared to what they are forecasting in their reports and projections. Rapid rates of change are not common in this industry. Technologies take a long time to scale from small deployment projects, to use by innovators and early adopters. Finally, the late adopter and laggard participants employ the new products to a saturation point where the value of the technology reaches most users. The work in this study is intended to accelerate adoption throughout all groups.

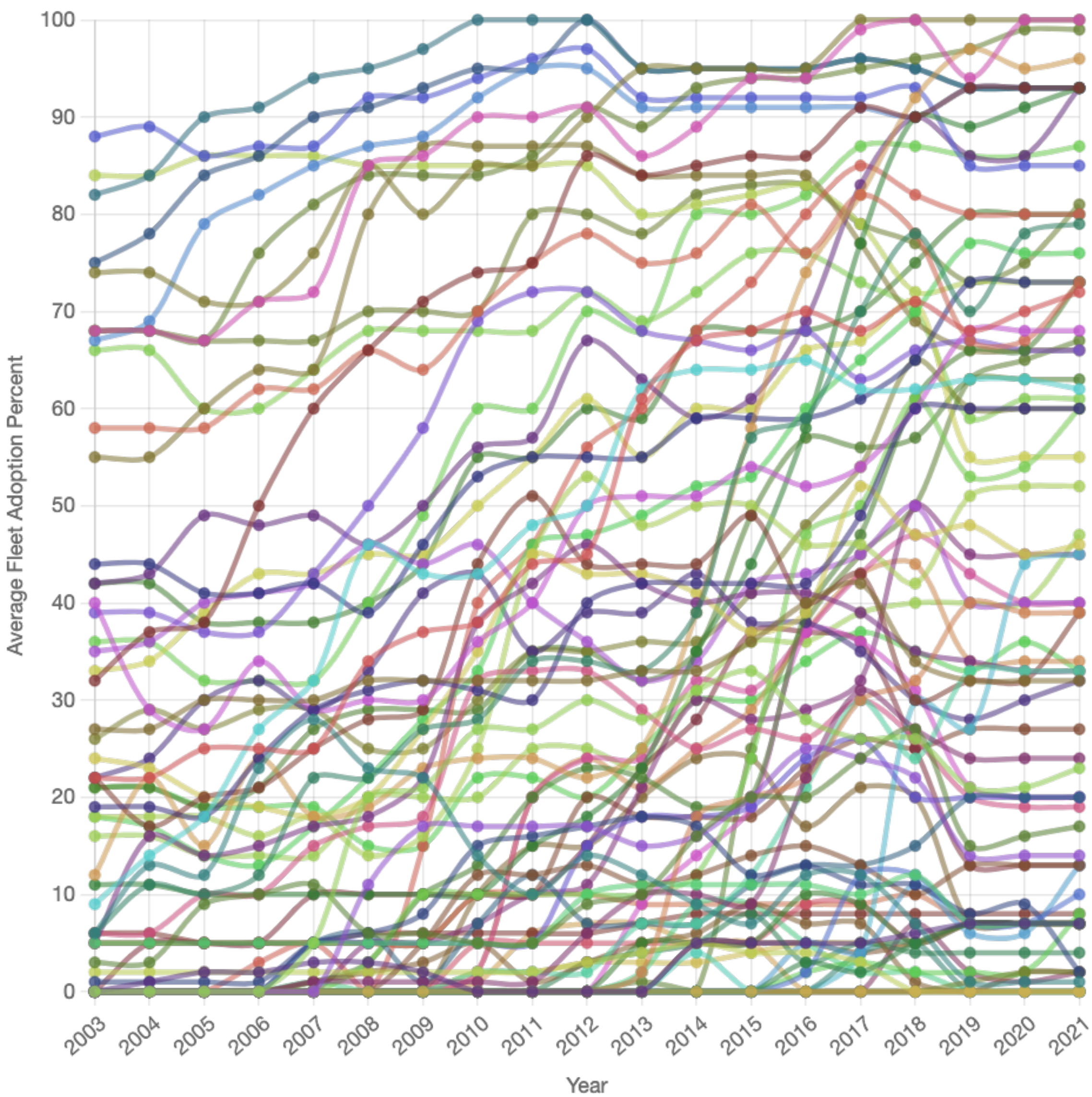


Figure 6: All 86 Adoption Curves

1.4 AFFS Enhancements

There are a couple of significant new enhancements to this years' Annual Fleet Fuel Study.

New for 2022 is an online version of the technology benchmarking tool. Users have the ability to complete their benchmarking online by each technology category in which they are interested or for all 86 technologies and receive a downloadable report. Each report will include the user's responses prioritized by the technologies that have the greatest gap between the user and the average of the AFFS fleets. In this first iteration of the online tool, duty cycle, application and other factors do not change the result. These factors may be incorporated in future versions depending on data availability and user response to the online benchmarking tool.

The report gives fleets not participating in the study insights into actions they can take to lower their fuel expenses and emissions. Additionally, by using the interactive tool, fleets also contribute to the growing database of technology adoption data. This is at no cost.

Each AFFS is unique and NACFE suggests that those who find this report highly helpful should review all previous reports for insightful information.

1.5 Adoption Calculations' Methodology

The percent adoption of a technology is a measure of the rate at which fleets purchased a given technology or implemented a given practice in any year. These technology adoption curves, commonly called S-Curves, given their shape, are used to describe how a new product is purchased over time. Over the years, NACFE has developed two measures of adoption. See Figure 7.

1. This first, ***Fleet Decision Adoption***, has a goal of determining adoption in terms of each fleet's technology selection and use. This methodology counts each fleet's decision the same. Therefore, the adoption percentage is not weighted by the number of tractors or trailers purchased per year by the fleet. It measures fleet decisions, rather than the number of trucks with the technologies. Using this methodology, a decision made by smaller fleets that purchase about 100 trucks per year, has the same value as that of the largest fleet buying thousands of trucks. The calculations for the data provided in the data set are as follows:

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

2. The second, ***Technology Unit Adoption***, provides a truer representation of the absolute number of new technology products sold each year. In this case, the data is recalculated using the miles traveled by each fleet. This methodology therefore does value a purchase of 2,500 trucks per year with a given technology by a large fleet as 25 times greater than a fleet buying only 100 new trucks.

Fleet DECISION Adoption	Technology UNIT Adoption
Counts each fleet's decision equally	Counts each piece of equipment with the technology equally
Illustrates the number of fleets that have adopted	Illustrates the total number of vehicles now equipped
To be used to understand fleet preferences	To be used to understand actual unit sales of a given technology

Figure 7: Comparison of Adoption Methodologies

Armed with this powerful data, much can be learned about the past and inferred to help forecast the future uptake of these features. The opportunity is enormous as there are about 1.7 million tractors operating in the US consuming approximately 26 billion gallons of diesel fuel. Every 1% reduction in fuel use saves 260 million gallons of fuel or about $1.4 billion per year, based on $5.34 price of diesel reported by EIA on October 22, 2022.

2 Price of Fuel

We would be remiss if we did not address the subject of the recent increase in fuel prices to historic highs in 2022. See Figure 8. In fact, in ATRI's Critical Issues in Trucking — 2022, it was reported that fuel costs topped the list of trucking industry issues. [16] We have found that fleets not only use the current cost of fuel in their calculations but also look at the sensitivity of decisions for higher and lower fuel prices. Therefore, they factor in potential future fuel prices into their purchase decisions surrounding new technology and in their use of various practices to affect the amount of fuel consumed by their fleet.

Figure 8: Fuel Pricing (Photo: Dave Schaller)

It is important to remember that the US is not the only country that consumes crude oil. Developments in other parts of the world, including growing economies, will impact the price of crude and by extension the price of diesel. Diesel prices, like all other products, are subject to the laws of supply and demand. When demand goes up, prices usually increase as well. Similarly, if the supply goes down, such as a refinery going off-line, reduction in global production rates, natural disaster, political unrest in a high production country, or other factors, the prices will likely increase.

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

NACFE's *2019 Annual Fleet Fuel Study* found that there were other factors influencing a fleet's strategy to adopt fuel saving technologies and practices. Along with the current price of fuel, expectations around the future price, sustainability and regulations have emerged as reasons to improve efficiency. See Figure 9.

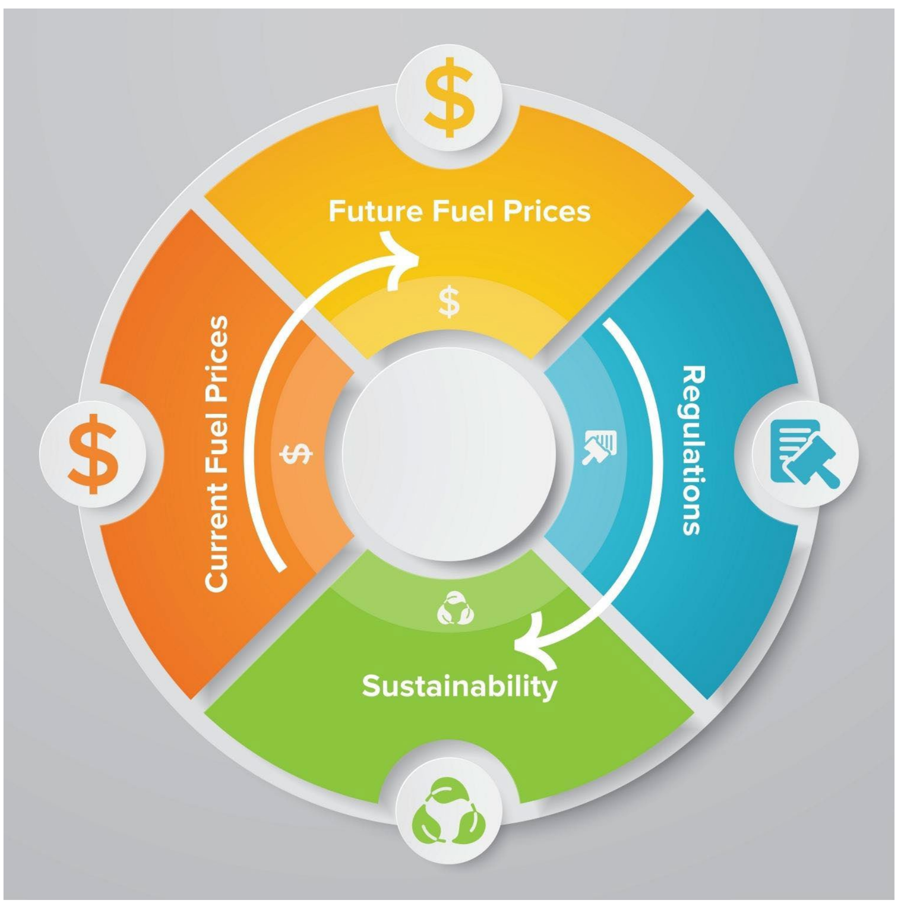


Figure 9: Factors Influencing Fleets' Decisions on Implementing Fuel-Saving Technologies

Greenhouse gas regulations, although not a direct requirement on fleets, do impact the equipment they must purchase to move goods. Being proactive with the truck, engine and other component manufacturers as they build equipment to meet the rules helps fleets purchase the technologies that the manufacturers must build.

In 2020 many trucking companies announced commitment to sustainability with strategies for achieving those goals in the 2040 to 2050 timeline. Many people did not take those commitments seriously because they seemed too distant. Things have changed today, and more and more fleets are indicating that shippers are asking them what they are doing to ensure that the company's goods are being transported in a sustainable manner. In some cases, shippers are even asking carriers about their plans regarding electric vehicles.

And finally, public demand for companies to operate in a more sustainable manner has reached all organizations including carriers. Consumer-facing brands also are feeling pressure to move forward quickly when it comes to reducing or eliminating emissions. Whether a consumer-facing brand moving their own goods or a carrier with a less familiar name, companies are taking action on sustainability.

3 Technology Adoption by the Fleets

This section describes the technology adoption with respect to fleet diversity, individual technology curves, and the consistency of technology adoption across the fleets.

3.1 Fleet Adoption Diversity

As is true for nearly all products, be they business-to-consumer or business-to-business, trucking end users tend to fall into different categories when new offerings become available. Some adopt early while some wait to learn from the experience of others — depending on their own calculations of the benefits versus the risks of being on the leading edge of new technologies. The 24 fleets (identified as fleets A to X due to privacy agreements) in this study are no different. See Figure 10. Over the course of the study, five fleets have had adoption rates of more than 50%, as defined in this report, while 11 have been between 40% and 50%. The first five were the most aggressive adopters in 2018, but a closer look shows that two of them were not always leading. Two fleets, A and D, moved from under 20% in 2003 to more than 50% in 2018, showing a remarkable increase in use of these efficiency technologies. They became very committed to specifying these technologies on their new equipment.

It is important to note that no fleet could adopt all technologies on a single tractor-trailer combination, as some are "competing" solutions for a single function. For instance, a truck would not have both a diesel auxiliary power unit and a battery heating, ventilating, and air conditioning (HVAC) system. The maximum adoption by a fleet would be around 65%, depending on the set of technology combinations. The fleets in this year's study range from having about 22% to 59% of the available technologies in use on their tractors and trailers.

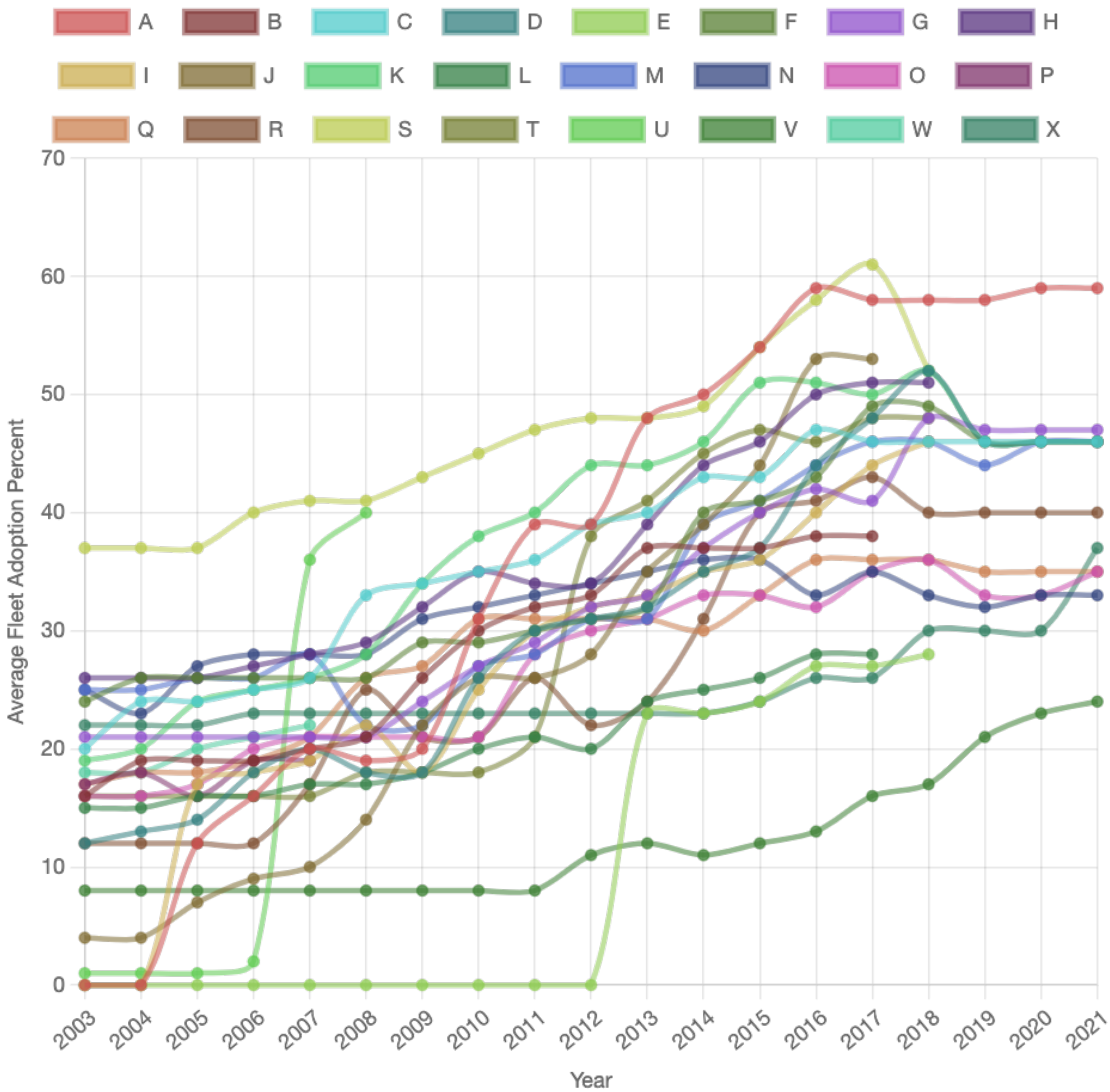


Figure 10: Fleet Adoption Percent Over Time

3.2 Technology Adoption Curves

Given the data provided, 86 adoption curves were created and are shown in the data set. Keep in mind that these charts show only the adoption practices of the 24 fleets studied, which represent about 5% of all heavy-duty over-the-road vehicles in North America. Also remember that two sets of data are included here, one where each fleet's decision is measured equally and a second where the value of larger fleets purchasing bigger quantities has a greater weight. This provides new insight into not only the current level of adoption, but also into the ramp up over the last decade. For example, the ramp up of the purchase of trailer skirts to more than 90% and automated manual transmissions to 93% adoption have the fastest adoption rate of all technologies.

The 86 technologies were grouped into seven categories: tractor aerodynamics, trailer aerodynamics, powertrains, tires/wheels, idle reduction, chassis, and fleet practices. Technology adoption by category is displayed in Figure 11, while the adoption curves for each technology are also provided. All categories show increasing levels of adoption with trailer aerodynamics increasing the most dramatically in the middle five years of the study and now powertrain having the biggest gain from 2013 to 2021.

Both tractor and trailer aerodynamics show a drop in adoption at the start of this new study period, 2019 to 2021. This is caused primarily by the mix of participating fleets this year versus prior ones. New study participants had a lower level of aerodynamic adoption than fleets that had participated before and did not supply data for this study.

All technology adoption curves are shown in the Appendix.

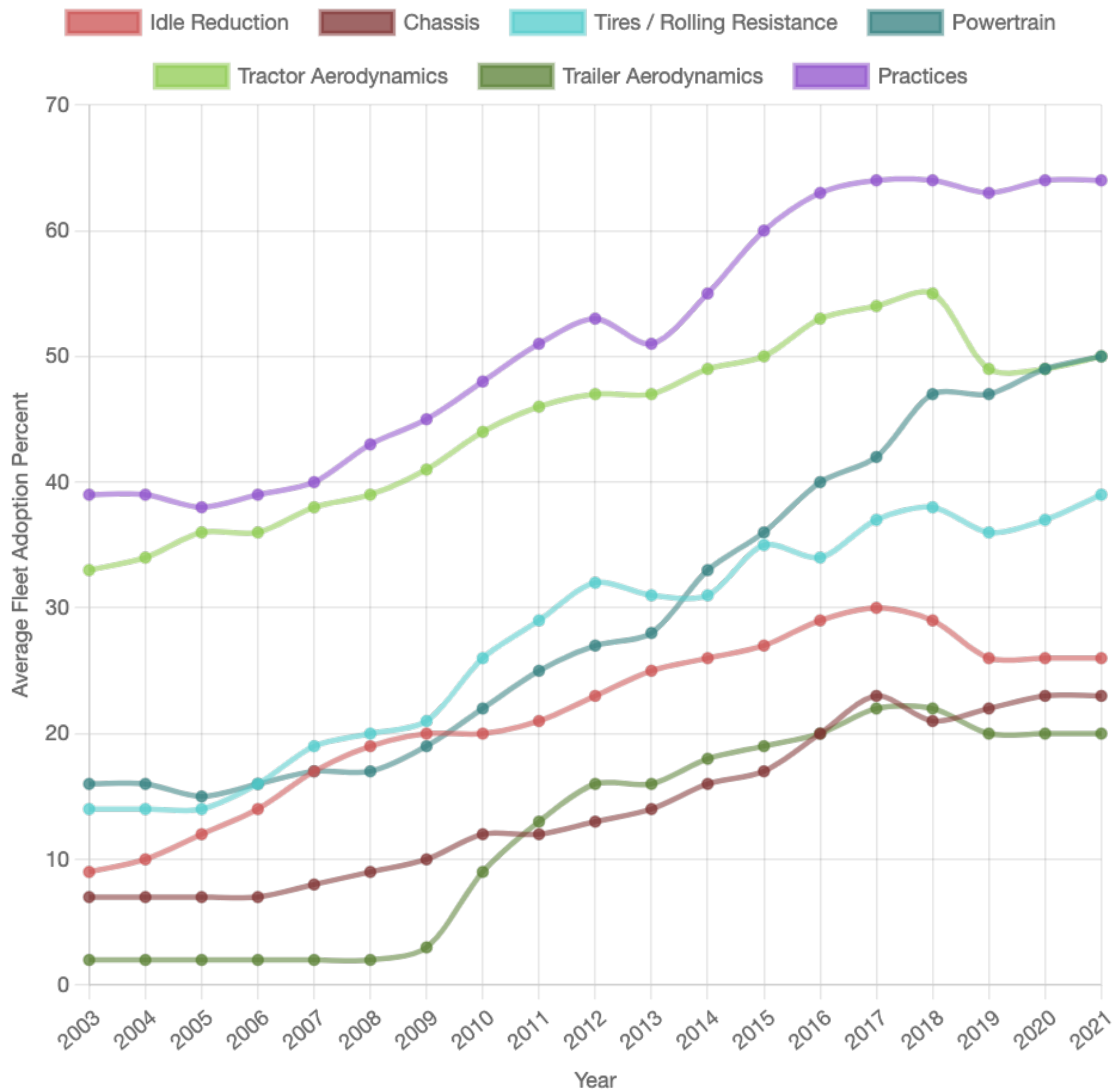


Figure 11: Fleet Adoption by Category

3.3 Fleet Individual Technology Adoption

Every year fleets in this study make decisions on their new truck and trailer purchases that affect freight efficiency. In some cases, they started buying new technologies, stopped buying some, continued to buy others, or increased or decreased the percentage of trucks and trailers with fuel economy devices.

The largest gainers in adoption by these fleets, when comparing their purchases in the three years ending in 2018 to those in the study period of 2019 to 2021, occurred with the technologies shown in Figure 12 (using the Technology Unit Adoption method).

Technology	Avg. 2019-2021	% Change
Automated Manual Transmissions	96%	16%
Lower Viscosity Engine Oil xW-30	91%	21%
Downspeeding (Rear Ratio < 2.7:1)	76%	17%
Remove Parts – Bug Deflectors, etc.	73%	19%
LRR Duals – Tractors	69%	40%
In-Cab Cameras	68%	24%
Shift to Neutral	65%	47%
LRR Duals – Trailer	60%	19%
Downsize Engine (e.g. 15L –> 13L)	52%	16%
Wheel Covers – Tractors	45%	22%
2.5 Speed/Variable Speed Water Pump	39%	40%
FA-4 High Efficiency Engine Oil	39%	235%
High Efficiency Alternator	33%	34%
Tire Pressure Monitoring – Trailer	20%	46%
Tire Pressure Inflation – Tractor	8%	23%
Tractor Solar Panels	7%	105%
Wheel Covers – Trailer	7%	43%
Vortex Generators – Trailer	7%	39%
Truck Stop Electrification (Snorkel Type)	7%	31%

Figure 12: Technologies with the Largest Increased Adoption

Figure 12 shows several powertrain technologies with increased adoption rates including automated manual transmissions and downsped powertrains. Low rolling resistance dual tires on tractors and solar panels on tractors continue to show gains.

Technologies shown in Figure 13 had the largest decrease in use in the study period of 2019 to 2021 compared to the three years ending in 2018.

Technology	Avg. 2019-2021	% Change
Routing Optimization	60%	-17%
Specified Weight Reduction on Tractor	55%	-19%
Vented Mudflaps – Trailer	34%	-18%
Light Paint Color: Solar Heat Absorption	32%	-19%
Tandem Fairings	20%	-40%
Platooning Capable	13%	-59%
Wide Base Tires – Trailer	19%	-28%
Battery HVAC	22%	-19%
Truck Stop Electricity with AC Power Port	14%	-42%
Engine Start/Stop for HVAC	16%	-33%
Tire Pressure Monitoring – Tractor	20%	-15%
Trailer Tail Fairings	7%	-65%
6x2 Axles	6%	-47%
Use of Hotels to Avoid Idling	7%	-38%
Diesel APU	1%	-93%
Trailer Nose Cones	7%	-28%
Smart Air Dryer/Compressor	7%	-39%
Automatic Transmission	7%	-72%

Figure 13: Technologies with the Largest Decreased Adoption

One area noted in the last two AFFS reports that continues to show a negative adoption situation pertains to the fleets that set their maximum cruise speed at less than 65 mph. As discussed in detail in the *2017 NACFE AFFS report*, many fleets and truckers have been driving faster in recent years. Several fleets increased the speed on cruise or on pedal during the study period. NACFE uses 65 mph as the threshold for this practice adoption. In Unit Adoption Rate, 66% of fleets in the study set maximum speeds below 65 mph versus a high of 84% that said they did so in 2016. Speed seriously affects fuel efficiency and this increase in speed negatively affected the fleet-wide average.

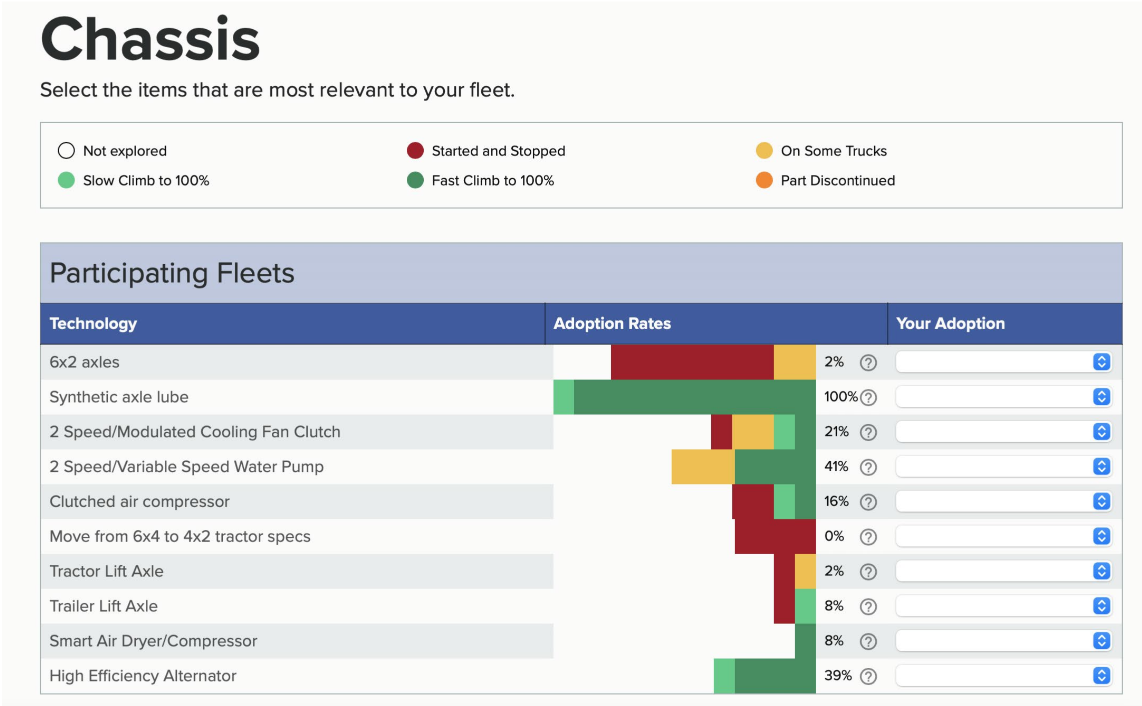
3.4 Fleet Consistency of Adoption

Finally, as in previous years' reports, NACFE evaluated the consistency of adoption by the various fleets. To do so, each of the 86 technology decisions (i.e., whether to adopt or not) made by each of the 15 fleets is compared using a categorization methodology showing whether the technology is being purchased by the fleet, how quickly the fleet moved from testing the technology on a few vehicles to specifying it on 100% of all purchases, or even if a fleet decided to stop buying something after initial deployment.

Figure 14 is a screenshot of the new interactive benchmarking tool which replaces the previous Excel-based versions. Each technology, grouped by category, is listed with the average adoption rate for all fleets in the most recent survey and a color bar indicating the proportion of fleets that have explored the technology and the rate at which they have adopted it. Therefore, a technology which has the color bar completely filled in (e.g., synthetic axle lube in Figure 14) are being adopted at 100% by all fleets in the survey. Since the bar is also all green, it indicates that all fleets that have explored the technology have adopted it in 100% of their new trucks.

A technology which is showing a wide red bar indicates that many fleets have explored the technology but have stopped using it. Technologies that have some green and some red in the adoption rate bar are interesting. A good example is the use of 6x2 axles, where 7 of the 14 fleets that provided adoption data started adopting and now have stopped (red squares). This could indicate that the technology is suitable to some applications or duty cycles and not others.

Fleets can interact with this data by entering their adoption rate for each technology on their newest purchases. After their adoption rate is entered, a downloadable report is available comparing their responses to the AFFS fleets, sorted by the technologies that have the largest gap to their own adoption.



Chassis

Select the items that are most relevant to your fleet.

- Not explored
- Started and Stopped
- On Some Trucks
- Slow Climb to 100%
- Fast Climb to 100%
- Part Discontinued

Participating Fleets

Technology	Adoption Rates	Your Adoption
6x2 axles	2%	
Synthetic axle lube	100%	
2 Speed/Modulated Cooling Fan Clutch	21%	
2 Speed/Variable Speed Water Pump	41%	
Clutched air compressor	16%	
Move from 6x4 to 4x2 tractor specs	0%	
Tractor Lift Axle	2%	
Trailer Lift Axle	8%	
Smart Air Dryer/Compressor	8%	
High Efficiency Alternator	39%	

Figure 14: Adoption Diversity

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

- Consider the technologies shown across many fleets as green, the most commonly adopted by the fleets in this study, for specifying on your next tractor and trailer. Ask yourself very specifically, *why are you not buying these technologies?*

- Investigate the technologies where some, but not all fleets are buying 100%. These technologies likely have less uniformity of adoption by the fleets as they may be more specific to certain duty cycles or business models. At least some of these technologies will also offer good options for a fleet to consider purchasing. Ask, with respect to your fleet, *which of these technologies best fits your mode of operation?*

- Explore the technologies where many of the technologies are white or red in the table. Many of these technologies may be new to the market, so they may make sense for adoption down the road. *Ask yourself if any of them offer an opportunity for your fleet to be an innovative early adopter?* Or ask if they are not valuable technologies yet and need further development.

4 Overall Fuel Savings from Efficiency Actions

The data on the uptake of these technologies over time, shown in section 4.2, raises many additional questions. Among them:

- What impact do these technologies have on the fuel efficiency of the trucks in the fleet?
- What is the payback on the investment in each of these technologies?
- Other than the fuel savings and purchase price, what are the other benefits and consequences of adopting a technology?

The average adoption percentage and fuel efficiency of these fleets is shown together in Figure 15. The MPG shown is for all trucks in the fleet in that year, so it does include tractors and trailers procured in years prior to a fleet's decision to adopt any given technology. It is therefore expected that the fuel efficiency curve will lag the adoption curve by a few years, as older trucks with fewer or none of the technologies installed are phased out.

Adoption improved, in aggregate as it has in prior years, and helped to deliver fuel savings. Fleet-wide fuel economy across the fleets participating leveled off during the study period. For the 10 years from 2009 to 2018, fleet-wide fuel economy improved about 2.0% year over year before stalling from 2019 through 2021. See Figure 15.

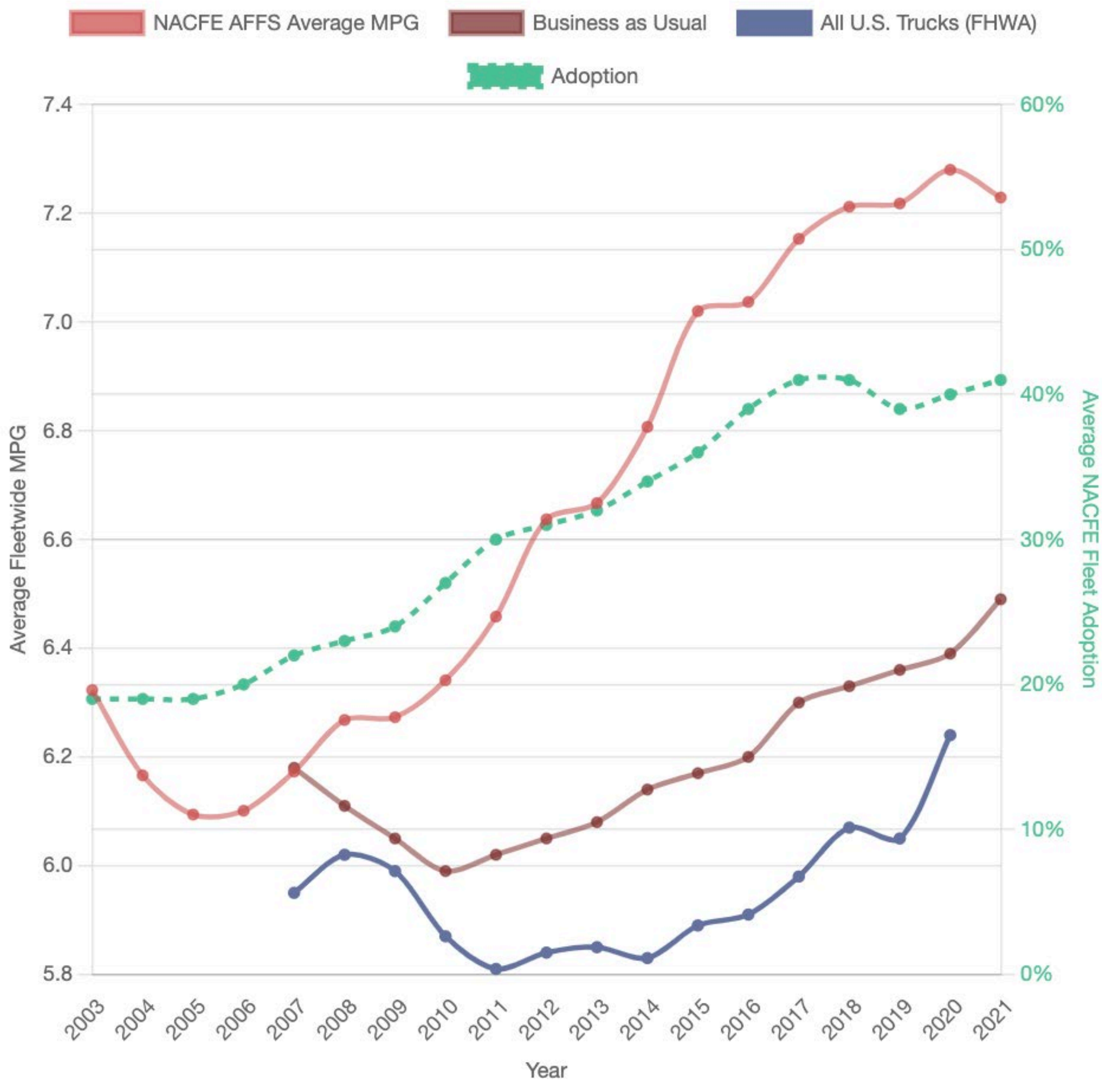


Figure 15: IFTA FHWA and AFFS MPG over the Study Period

You may note the early "U" shape of the Average MPG curve. In the first half of the period, 2003 to 2010, the impact of the introduction and purchase of engines meeting EPA04 and EPA07 emissions level requirements caused an overall decrease in fuel efficiency. In the period between 2007 and 2010, procurement of new fuel economy technologies at these fleets grew and began to stabilize the MPG, overcoming the degrading effect of the new engines. Finally, over the years 2011 to 2017, the average fuel efficiency of NACFE's study fleets improved due to a dramatic increase in the adoption rates of new fuel-efficiency technologies, along with the introduction of DEF in 2010, as well as the effects of the GHG emissions regulations on the base powertrain. In 2021, the fleet-wide average MPG of the combined fleet has risen to 7.23.

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

The fuel savings in 2021 between the BAU of 6.49 MPG and the NACFE fleets' average of 7.23 MPG amounts to $5,178 per year per truck, at the $3.29 per gallon fuel cost over the average tractor mileage of 100,000. The fleets are saving $7,207 over the national average of 6.24 MPG. If fuel costs had been at the five-year average of $2.94 per gallon, the savings would have been $4,635 and $6,452, respectively. And finally, the 15 fleets operating 75,000 trucks saved $540 million in 2021 compared to the average trucks on the road.

It is important to remember that this data is based on what fleets are currently doing to improve freight efficiency. We realize that in the future some fleets will be adding some battery electric trucks to their operations and that may change MPG savings. However, many of the technologies used to improve fuel economy will serve to extend battery range on battery electric trucks. The move to decarbonization includes burning less fuel in diesel-powered trucks, considering alternative fueled options and moving to zero-emission freight transportation.

A simple analysis was conducted on the payback of the technologies that provide most of the savings for these fleets. That review determined about a 2.8-year payback for those technologies. This payback will improve in the future as higher adoption leads to lower upfront purchase prices.

4.1 Fuel Economy at Different Levels of Adoption

Fleets adopt different technologies and do so at different rates. However, the more technologies a fleet adopts, the greater the opportunity to improve fuel economy and save on the annual cost of fuel for the fleet. If a fleet goes all in, they are more likely to see the biggest savings and that will lead to increased profits. See Figure 16.

Figure 16: Top fleets like Nussbaum adopt a variety of technologies to improve freight efficiency. Nussbaum is now using cameras instead of mirrors on some of its trucks for an additional 1.5% fuel economy gain. (Photo: Nussbaum)

NACFE has been tracking adoption rates and fuel economy of the participating fleets for many years. As shown in Figure 15 (MPG over study period), MPG for the general truck population has been increasing but the AFFS participants have improved their fuel economy at a faster rate as their adoption of fuel-saving technologies has increased. While the return on any one specific technology can be difficult to track, the overall approach of testing and adopting these technologies does yield a return for the participants. Fleets with a higher overall adoption rate of all technologies achieve better fuel economy than ones with lower adoption.

Figure 17 illustrates that this has been the case for the length of the Annual Fleet Fuel Study. For all years going back to 2003, participants were divided into groups based on their overall adoption rate for all technologies surveyed in that year. The adoption rate groups are as follows.

- Less than 30%
- 30 to 39%
- 40 to 49%
- 50% and higher

For each group, the average MPG was calculated by year. These were then combined into a rolling five-year average (to ensure that each group is made up of multiple fleets) shown in Figure 17. Figure 17 shows that higher adoption rates correlate to higher MPG throughout the 10+ years for which NACFE has collected data. Fleets with the highest adoption rates consistently achieve the highest MPGs. Of note is that early in the study, very few fleets had adoption rates greater than 30% and none were above 50%. In fact, the first fleet did not achieve an average adoption rate above 50% until 2014. The mix has shifted very rapidly over the years. Since 2016, more than half of the Annual Fleet Fuel Study participating fleets have had an average adoption rate above 40%.

It is worth mentioning that the data shown in Figure 17 should be treated with caution since it is made up of averages reported by fleets operating many different pieces of equipment in varying duty cycles and applications. Figure 17 should be viewed as indicative of an overall relationship and does not prove causation. It is possible (and maybe even likely) that fleets with high adoption rates have other practices not measured in this data which also contribute to better fuel economy. But it does reinforce the fact that fleets with an ongoing focus on high MPGs, which includes constant testing and adopting of fuel-saving technologies, are achieving better results.

There are signs in the data that not all technologies are suited to all applications and duty cycles. The fact that the 30% to 39% MPG line occasionally weaves above and below the adjacent MPG lines may be because some technologies, even ones that are popular and widely adopted, yield a much lower return than others, another indication that fleets need to test and analyze their data.

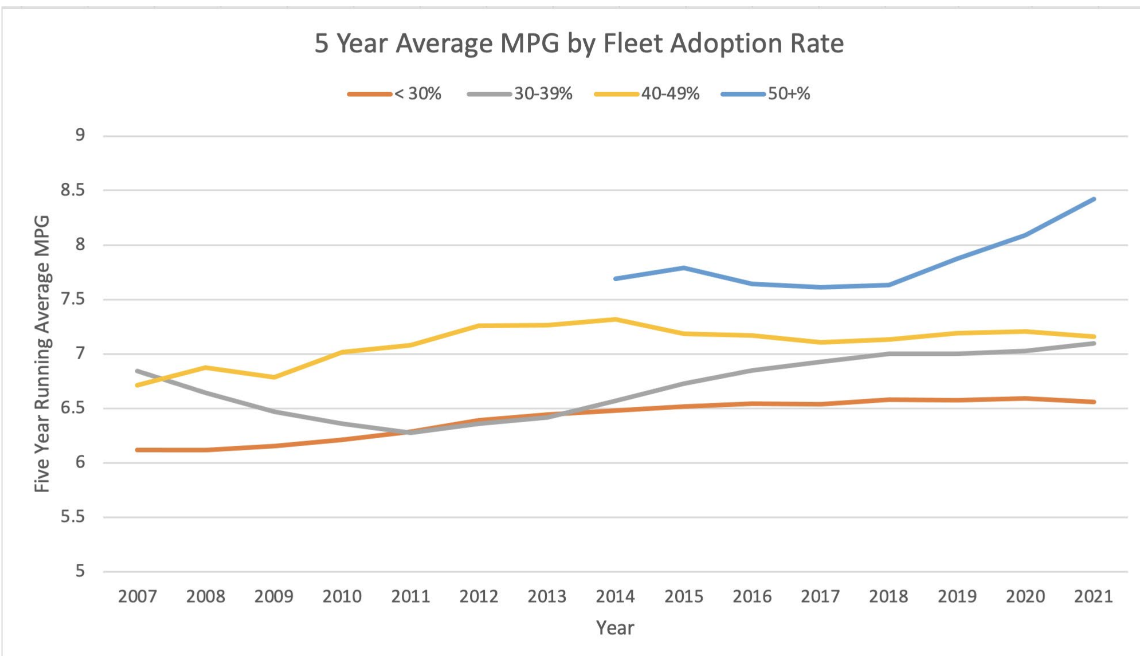


Figure 17: Five-year Average MPG by Adoption Rate Group

5 Efficiency and Content of Latest Equipment

Since 2010 with the introduction of SCR engines, the truck OEMs have been able to make every successive model year truck more efficient than the one preceding it. This decade plus of compounding gains in efficiency combined with increased adoption of fuel-saving technologies has saved the industry enormous amounts of fuel and put MPGs once considered to be in

SuperTruck territory within reach of regular production level vehicles. It is encouraging to see that even after all these years of gains, manufacturers and fleets continue to find ways to make and operate their vehicles more efficiently.

5.1 2022 Model Year Trucks

By 2021, the fleets in this study had adopted many of the 86 technologies, though each fleet has chosen its own unique suite of technologies and practices. It is difficult to compare the fuel efficiency of different fleets as they vary in terms of the cargo they haul (weight), the geography and climate they operate in, and their business model for freight movement. Other variables such as driver makeup, company drivers versus independent contractors, length of time they plan to own the equipment, etc. also will have an impact on adoption decisions.

For this study, the fleets provided NACFE with fleet-wide fuel-efficiency data and required that we publicly share only aggregated averages of that data; they did not generally provide data for their equipment by model year. However, during this year's data collection, NACFE did obtain and discuss some of the fuel-efficiency results obtained by many of the fleets with respect to their 2022 model year equipment and how they operated in 2021.

This research concludes that these fleets are operating their newest vehicles in a range of 7.5 to 9.5 MPG. Some trucks were even found to deliver 10 MPG in certain routes, conditions, and seasons. One fleet is using these improved truck and trailer specifications and operations to consistently have a fleet-wide fuel efficiency at more than 9.0 MPG. This rate of improvement stems from three areas:

- The purchase of efficiency technologies,
- The fact that the improvements delivered by diesel exhaust fluid-equipped (2010 emission) trucks have reached saturation, and
- Most recently the gains from some base engine improvements made in response to the GHG emissions rule.

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

5.2 Run on Less by NACFE Performance

In 2016, NACFE decided to find the best of the best in real-world fuel efficiency and embarked on what has now become Run on Less by NACFE. To date, three events have been conducted, two of which focused on diesel heavy-duty Class 8 tractor-trailers, one in 2017 and another in 2019. Another event in 2021 featured battery electric vehicles. All three events have been a joint effort between NACFE and RMI.

5.2.1 2017 Run on Less

The first Run on Less was conducted in 2017 with a focus on long-haul operations. It occurred during September 2017 and concluded at the inaugural North American Commercial Vehicle show in Atlanta. A full report from the event can be downloaded here. The team studied the various actions that the seven participants used to reach the high level of performance and summarized it in Figure 18, *10 Actions for 10 MPG*. This is a roadmap for areas of focus for fleets and manufacturers to move the entire industry to higher levels of performance.

Figure 18: Run on Less 10 for 10 Infographic

In total, the seven trucks averaged 10.1 MPG over the 17 days of the inaugural Run on Less. This was compared to a national average of 6.4 MPG for the over-the-road tractor-trailer population. A rationale for defining over-the-road efficiency is shown in the full Run on Less report in a section titled Average Performance of the North American Fleet on page 33. The trucks in the Run covered a total of 50,107 miles at an average gross weight of 55,498 lbs. As expected, the distribution of daily average MPG is centered between 10.0 and 10.5. Five truck-days (one truck on one day equals a truck-day) were between 7.0 and 8.0 MPG and four truck-days were between 12.5 and 13.0 MPG. See Figure 19.

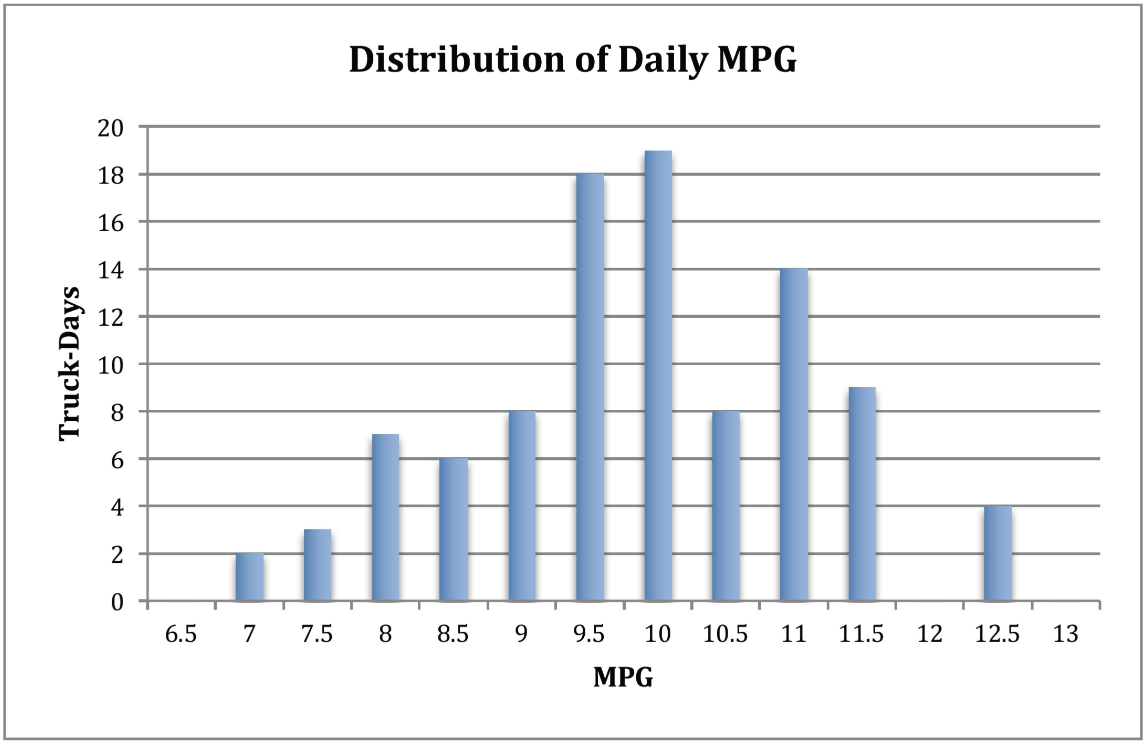


Figure 19: Daily Run on Less MPG

There were 99 truck-days during the 17 days of the Run. The trucks totaled 543,903 feet in elevation gain, and dealt with various weather conditions, including the effects from Hurricanes Harvey and Irma. The overall average speed during the Run was 54 mph. Keeping speeds low is one method drivers can use to reduce their fuel consumption. Several of the drivers kept their highway speeds below 60 mph for much of Run on Less although others spent most of their time in the 62 to 64 mph range. While all drivers recorded some time above 65 mph, very little time was spent at 68 mph or higher. The drivers kept idle time very low, aided by the available array of idle reduction technologies, and the fact that the event occurred for two and a half weeks in September when temperatures are moderate.

5.2.2 2019 Run on Less Regional

The second Run on Less was conducted in October 2019, this time focusing on the more challenging segment of the market — regional haul. A full report from the event can be downloaded here. NACFE defined this as a return-to-base operation with the routes remaining within a 300-mile radius of the domiciled location. Ten fleets participated running various distinct duty cycles including out and back, hub and spoke and multiple drops. NACFE used Geotab and LinkeDrive data to display each of the 135 days of driving to detail the duty cycles and environmental conditions during the Run. Figure 20 shows two of those graphics depicting an out and back and a multi-stop day of driving.

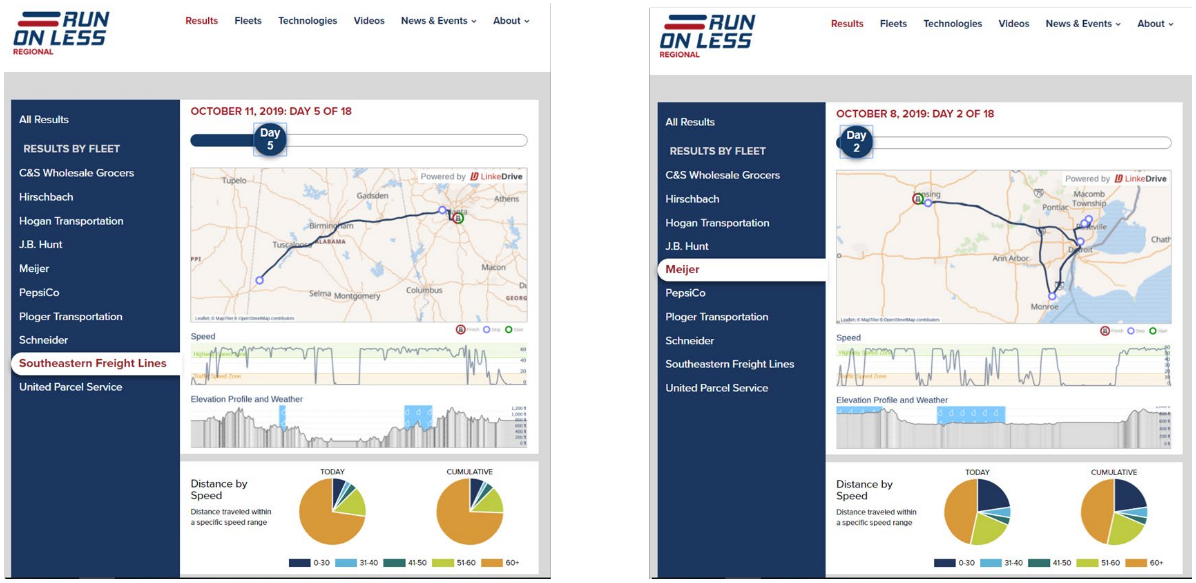


Figure 20: NACFE Run on Less Regional Duty Cycles

The 10 trucks averaged 8.3 MPG; that included one of the trucks powered by compressed natural gas, which did quite well for a CNG tractor. The remaining nine diesel trucks averaged 8.7 MPG. If all the 800,000 trucks operating in North America in regional applications were at this level of performance, more than $9 billion dollars would be saved.

During Run on Less Regional, NACFE instrumented the trucks with dataloggers to better calculate the actual payload moved during differing segments of each day's drive. This calculation is incredibly difficult to measure consistently and NACFE will continue its efforts to better understand payload. Much was learned during the month of the Run with more than 30 videos, fleet details and data that can be viewed at www.runonless.com.

5.3 Benchmarking MPG

There have been other efforts to improve the fuel efficiency of moving goods with large trucks. The US Department of Energy (DOE) helped fund four SuperTruck 1 teams to build prototype tractors and trailers that would double freight efficiency. Four teams created equipment that reported fuel economy in the 10 to 12.5 MPG range. Results of these truck program demonstrations were reported by the teams at the DOE Annual Merit Reviews in 2015 and 2016. [5] Five SuperTruck 2 projects are nearing completion here at the end of 2022 and surpassing the levels of their SuperTruck 1 prototypes. Results of final testing will become available throughout 2023. [15]

Figure 21 provides a comparison of the various benchmarks of Class 8 tractor-trailer performance mentioned so far in this report. Shown are:

- The national average of all US Class 8 tractor-trailers at 6.24 MPG in 2020,
- The NACFE AFFS fleet-wide average of 7.23 MPG in 2021
- The Department of Energy SuperTruck 1 trucks ranging from 10 to 12.5 MPG.

- The Run on Less 2017 performance of 8.5 to 11.5 MPG,
- The NACFE AFFS latest model year truck range from 7.2 to 9.5 MPG in 2018, and
- The Run on Less 2019 Regional results of about 6.5 to 9.6.

There continues to be a multitude of developments underway that are sure to continue the performance increases in efficiency of these trucks. Such efforts include the Shell Starship initiative, DOE SuperTruck 2 effort, which now includes five teams, the developments underway for commercial battery electric vehicles, hydrogen fuel cell electric vehicles, diesel hybrid trucks, and on and on.

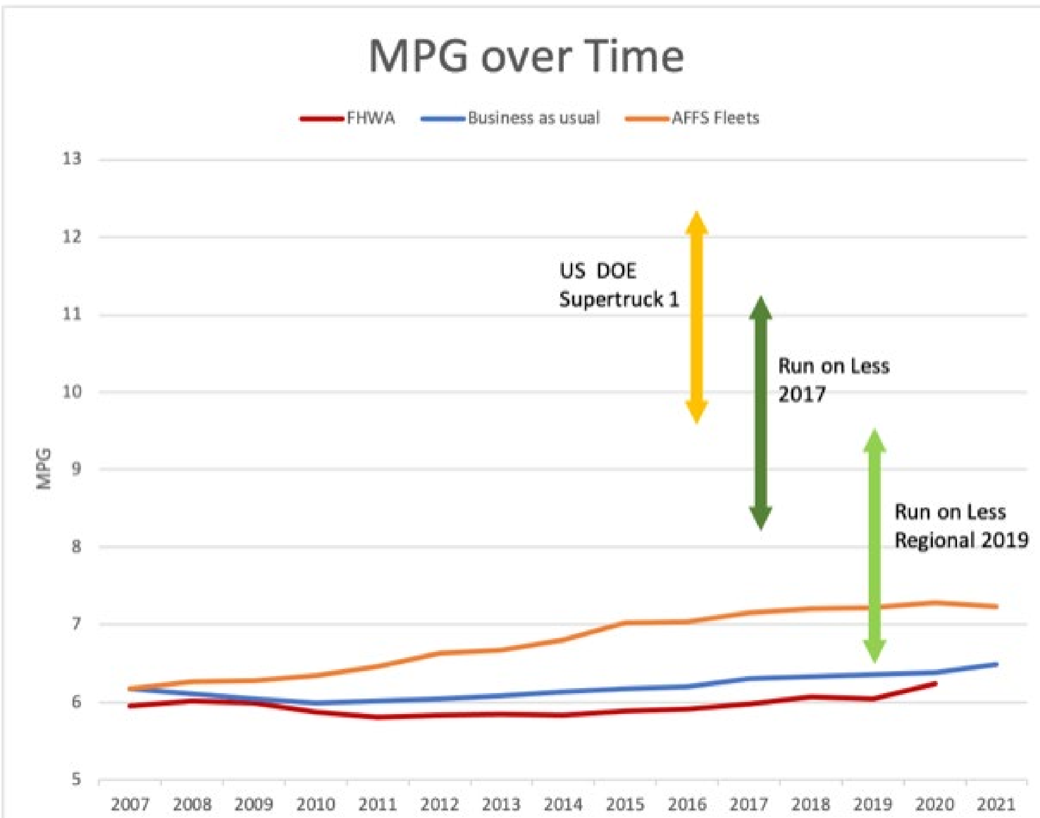


Figure 21: Mileage Comparisons

5.4 Why Not Ton-Miles per Gallon?

NACFE uses miles per gallon as the common performance metric in these studies as it is provided by fleets through their IFTA reporting and published by the federal government. It is also a commonly referenced metric as it is relatively easy to measure. As discussed in depth in NACFE's Run on Less report, the conditions that contributed to the MPG really matter. These include such items as payload carried, speed driven, wind and other environmental conditions as well as the elevation change of the journey. Many projects are beginning to use Ton-Miles per Gallon as a metric which considers the payload hauled by the truck during a given freight hauling segment. The recently completed Starship 2.0 project by Shell (Figure 22) is an example where this freight ton efficiency metric was heavily used.

Figure 22: Shell Starship (Photo: Shell)

It is difficult to determine the actual loads in any given route, let alone day or year, and in some situations a load will cube out, the trailer fills with freight, before reaching a maximum weight limit. Given these challenges, NACFE will continue to use MPG as the primary metric for the Annual Fleet Fuel Study. The group will continue to understand the amount of goods hauled, either in tons or cubic dimensions and share findings whenever possible.

6 NACFE Confidence Reports

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

Confidence Reports provide a concise introduction to a promising category of fuel-efficiency technologies, covering key details of their applications, benefits, and consequences.

As of the release of this report, the group has finished in-depth work on available technologies, shown in Figure 23, such as tire pressure systems, 6x2 axles, idle reduction solutions, electronically controlled transmissions, optimizing engine parameters, low rolling resistance tires, downspeeding, lightweighting, maintenance for fuel economy, tractor and trailer aerodynamics, and low viscosity engine lubricants.

NACFE also publishes Guidance Reports on emerging technologies such as battery electric vehicles and autonomous trucking.

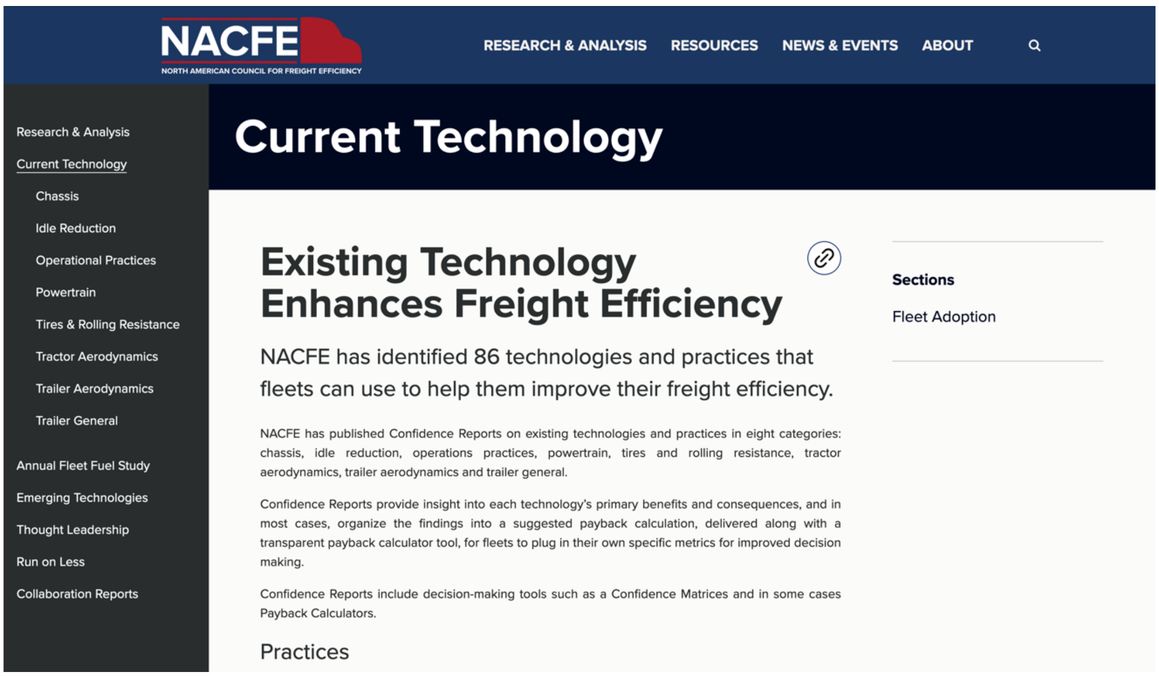


Figure 23: NACFE Confidence Reports

7 Value of Technology Adoption

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

Some technologies such as automated manual transmissions and diesel auxiliary power units cost thousands of dollars, but offer significant benefits, and therefore possibly acceptable paybacks. Other technologies such as vented mudflaps or wheel covers cost little, while others such as optimizing engine parameters or choosing light-colored exterior paint cost nothing at all. For each technology studied, the team offers a confidence matrix. Figure 24 shows an example of such a matrix from the recently published Confidence Report on Lightweighting [14].

These illustrations locate the technology in question on a grid comparing simple payback in years (value) with the amount of information and performance data available (confidence rating). Fleets should have high confidence in immediately pursuing technologies in the upper right quadrant, as those technologies have a short payback and are proven to impact their operations in a very positive manner. Technologies to the top and left of the matrix are those for which there isn't a significant amount of information available, but what data is available suggests they would be very good for most fleets. As more information becomes available to the NACFE team, these ratings and the information online will be updated.

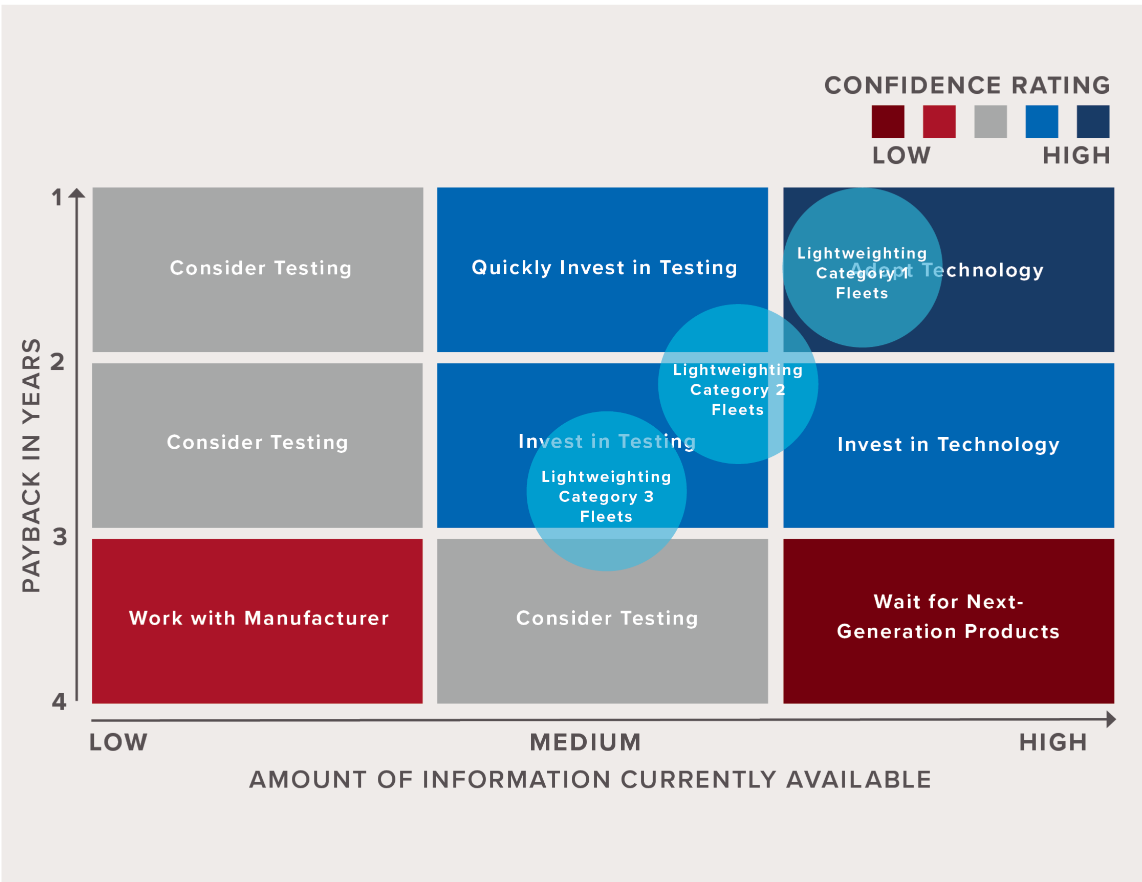


Figure 24: Confidence Matrix for Lightweighting (NACFE, Lightweighting, 2021)

8 Conclusions

The results of the AFFS clearly reflect a growing use of fuel-saving technologies and practices and 2022 provided another interesting set of data. Following are the high-level conclusions reached by the study team this year.

1. **Study fleet-wide fuel efficiency stalled from 2018 to 2021.** After an average year-over-year increase of 2% from 2011 through 2017, fleet-wide average from these benchmark fleets was flat at 7.24 MPG from 2018 through 2021. NACFE received input from the participating fleets and other fleets, OEMs and manufacturers as well as other groups and determined this was caused by the following factors.
    - Given the large amount of freight to be moved during these times and the challenges of driver attraction and retention, many fleets have increased their cruise and pedal highway speeds. In fact, fleets with maximum speed limiters under 65 mph have declined from 84% in 2016 to 66% in 2021. This results in a significant increase in fuel consumption with a 0.1 MPG hit for every 1 mph increase in average speed.
    - Given increases in productivity and supply chain challenges, fleets have been keeping trucks longer. As truck builders have been bringing better MPG trucks to the market each model year, this decreases the number of new trucks in the study.
    - GHG phase 2 regulations have required manufacturers to bring improved base engine and truck MPG particularly in 2017 and 2021 when compliance steps were required. However, the fleets in the study have decreased their adoption of optional fuel efficiency features. Examples include 6x2 axles, rear trailer aerodynamics, idle reduction technologies, and tractor tandem fairings and tractor wheel covers.
    - Anecdotally several fleets have told NACFE that their idle times have increased in recent years. COVID-19 restrictions and possible concerns about Covid in general have led to drivers spending more time in their bunks. This, combined with a reduction in the adoption of battery HVACs and diesel APUs contribute to an overall decline in MPG.
    - Another factor contributing to the lower MPG was the fact that a few new fleets with lower levels of aerodynamics adoption replaced some other fleets that had higher adoption rates and efficiency. This was a function of the fact that regional haul fleets replaced long-haul fleets in this year's Annual Fleet Fuel Study and traditionally regional fleets install fewer aerodynamic devices.

2. **All heavy-duty tractors in the United States have improved efficiency in the past few years.** For all of the heavy-duty combination vehicles, Class 8 tractor-trailers, the national MPG average has increased rather sharply in the last three years from 5.98 MPG to 6.24 MPG. As the higher MPG delivered by model year 2010 to 2018 trucks have found their way into replacing older trucks the average is increasing. Tractor life is generally in the 10-to-15-year range, so trucks being bought in the five-year replacement cycle can have an MPG increase of one to two MPG.

3. **Sustainability has become a large driver for fleets to decarbonize the way they move goods.** Corporations are responding to an increased demand by their shipping customers and the general public to move goods more sustainably. The industry is not waiting for zero-emission solutions to do this, as improving freight efficiency on diesel tractor-trailers is a key decarbonization strategy that saves emissions now. At the IAA

Transportation 2022 trade show, Jennifer Rumsey, CEO of Cummins, talked about the company' strategy for getting its products to net-zero emissions levels and said there are a variety of ways to do that. "Improving fuel economy doesn't always grab the headlines, but it adds up to real results."

- Items such as aerodynamics, tire rolling resistance, speed management, maintenance, idle reductions implemented now will increase the range of alternative and zero-emission vehicles as they are adopted. This is very significant.
- Decarbonization does not mean only a move to zero-emissions freight movement. Improving MPG of diesel tractors and trailers with these technologies is a clear effort to burn less fuel and reduce carbon emissions.

4. **Regulations will drive freight efficiency through the next two decades.** GHG 2024 and 2027 steps are coming quickly. The GHG phase 2 regulations have steps for the OEMs to comply with in Model Years 2024 and 2027. These are significant MPG improvements that will have OEMs develop, offer and sell new features on their tractors and trailers that will show up in this study in future years. NHTSA and the EPA have announced studies for future efficiency regulations which will likely deliver a GHG phase 3 for implementation throughout the 2030s.

9 Recommendations

Based on findings from this year's AFFS, NACFE has developed some recommendations for fleets that are evaluating fuel-efficiency technologies.

1. Collect and monitor fuel consumption by vehicle. Fleet MPG improves vehicle by vehicle. Tracking fuel consumption by vehicle also allows a fleet to understand which duty cycles and applications are best for fuel efficiency, identify pieces of equipment that need to be maintained or replaced and reward or re-train drivers that may be over- or under-performing.
2. Commit to and budget for an ongoing plan of MPG improvement.
   - Set long-term MPG improvement goals. Many fuel-saving technologies have a high return on investment which will improve the profitability of a fleet.
   - Use the Annual Fleet Fuel Study benchmarking tool to identify technologies to test
   - Continuously track your progress
3. If possible, develop a test route and test driver with which to test new technologies. This can be a purpose-made route or an ongoing dedicated route where MPGs are fairly consistent.
4. If purchasing used equipment, purchase equipment from fleets known for having good fuel economy. These fleets are continually testing technologies and are adopting ones that are successful.
5. Allow for failure. Not all technologies will be right for your application and duty cycle. Do not let short-term failures derail your long-term goals.

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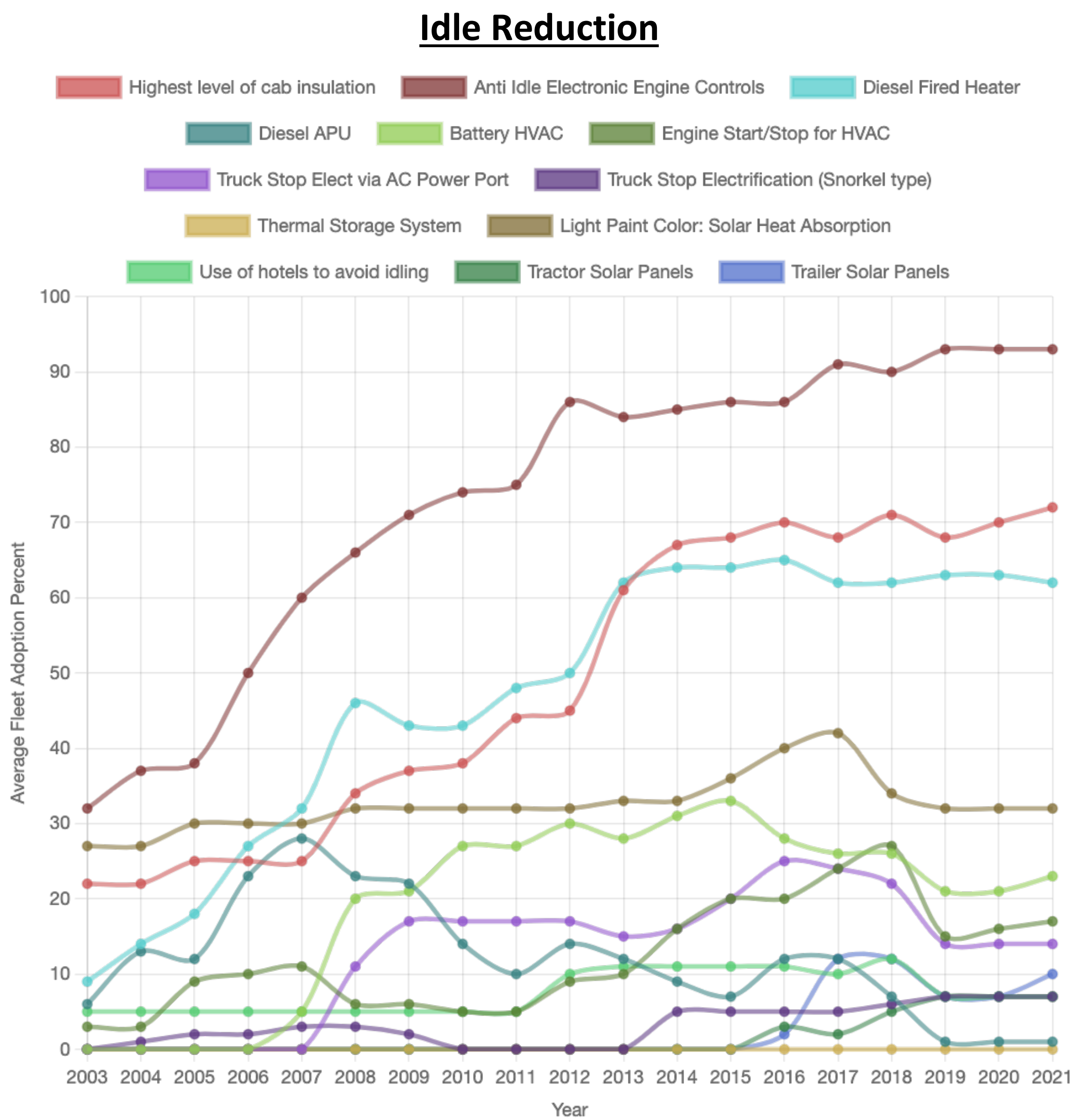
11 Appendix


Idle Reduction
Highest level of cab insulation
Anti Idle Electronic Engine Controls
Diesel Fired Heater
Diesel APU
Battery HVAC
Engine Start/Stop for HVAC
Truck Stop Elect via AC Power Port
Truck Stop Electrification (Snorkel type)
Thermal Storage System
Light Paint Color: Solar Heat Absorption
Use of hotels to avoid idling
Tractor Solar Panels
Trailer Solar Panels
Average Fleet Adoption Percent
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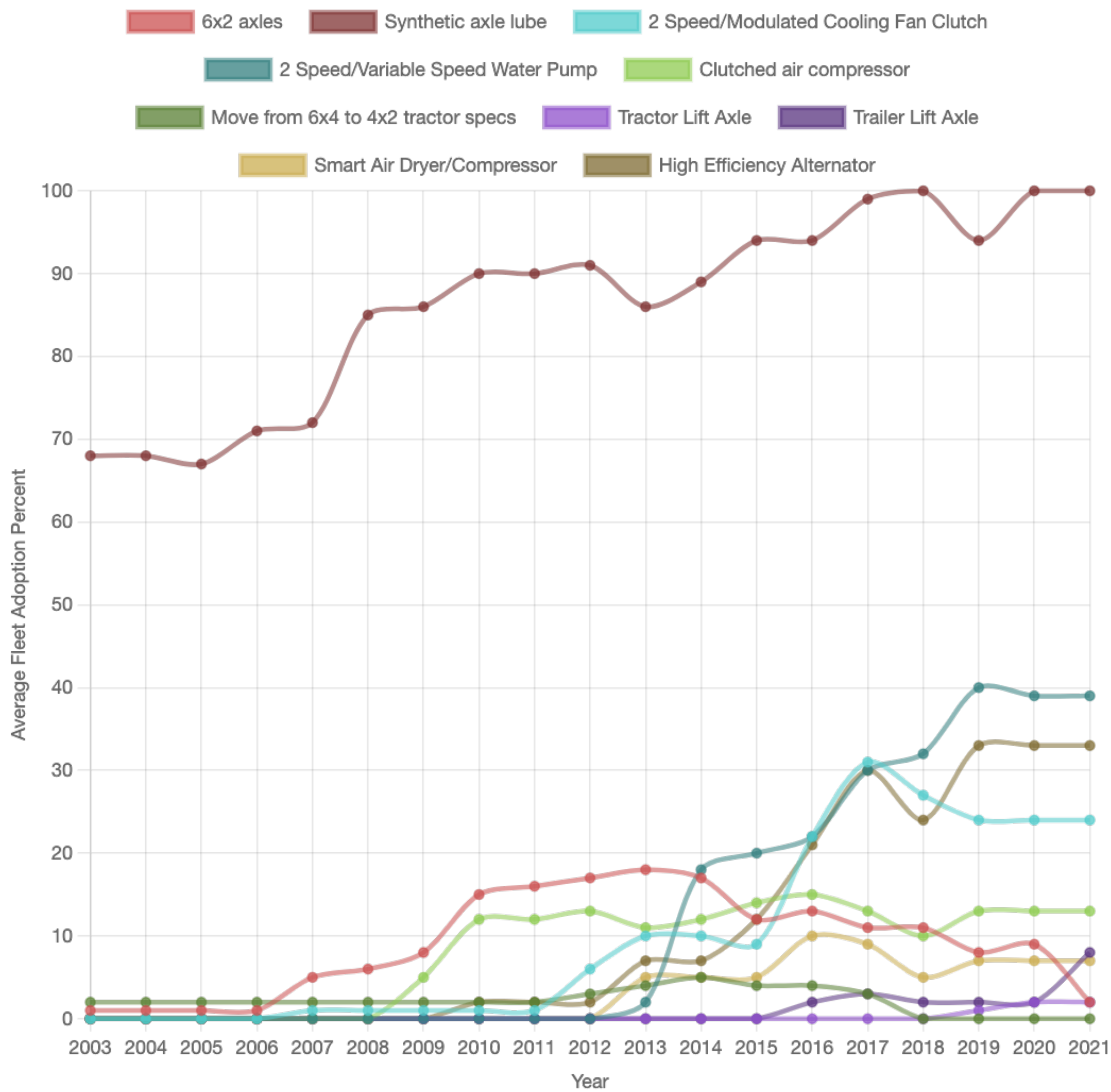
Chassis


6x2 axles
Synthetic axle lube
2 Speed/Modulated Cooling Fan Clutch
2 Speed/Variable Speed Water Pump
Clutched air compressor
Move from 6x4 to 4x2 tractor specs
Tractor Lift Axle
Trailer Lift Axle
Smart Air Dryer/Compressor
High Efficiency Alternator
Average Fleet Adoption Percent
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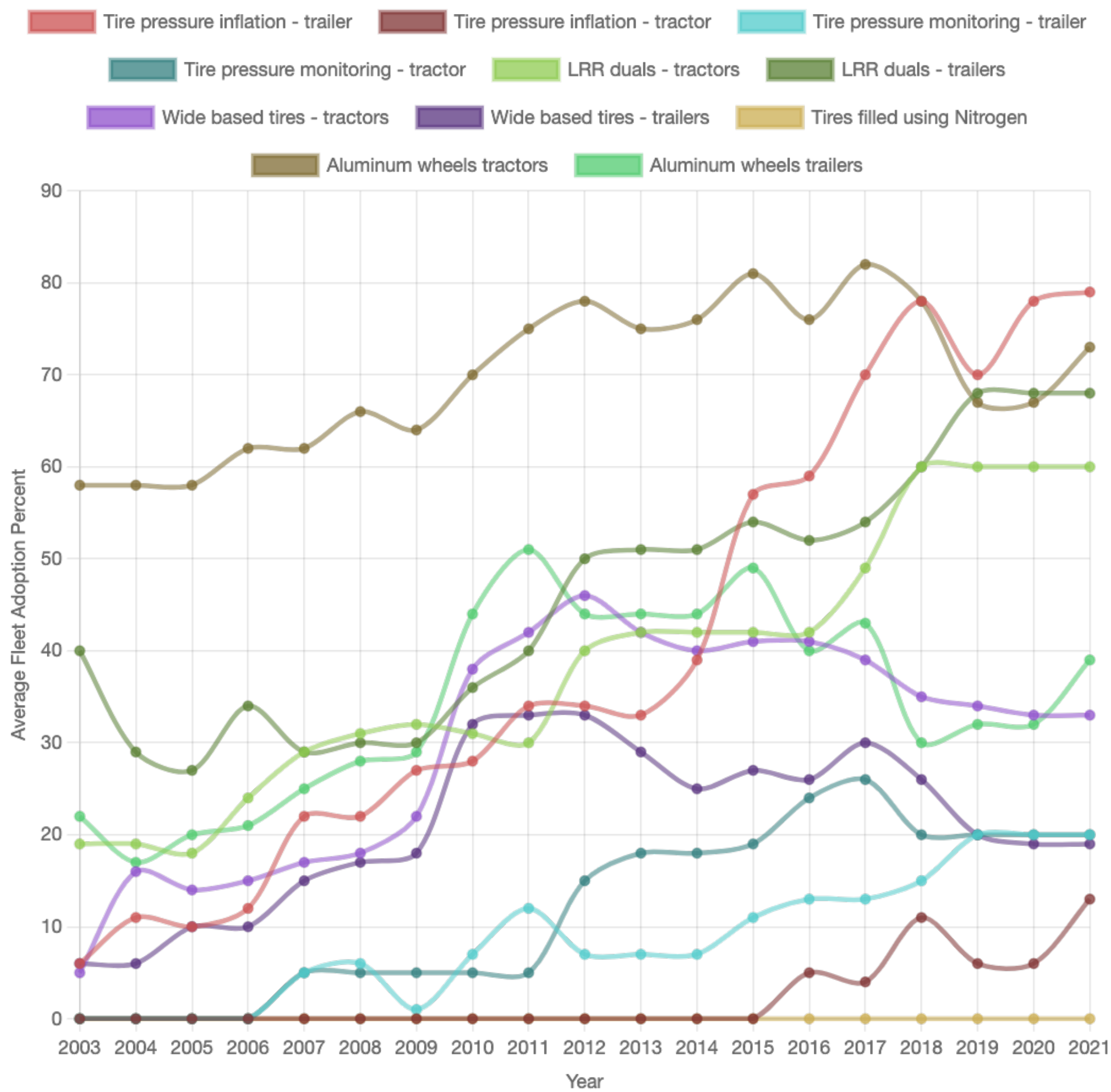
Tires, Tire Inflation, Wheels



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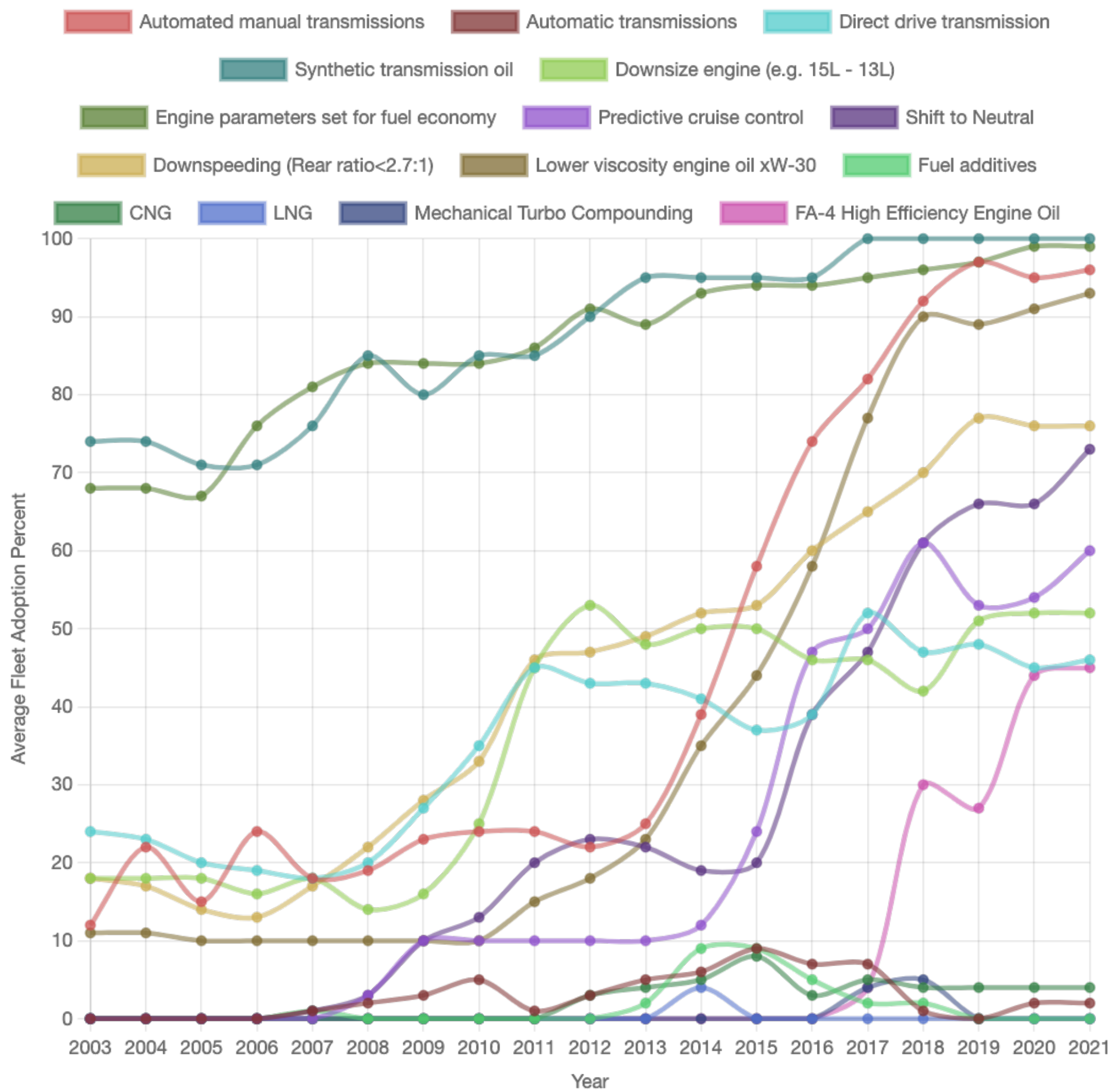
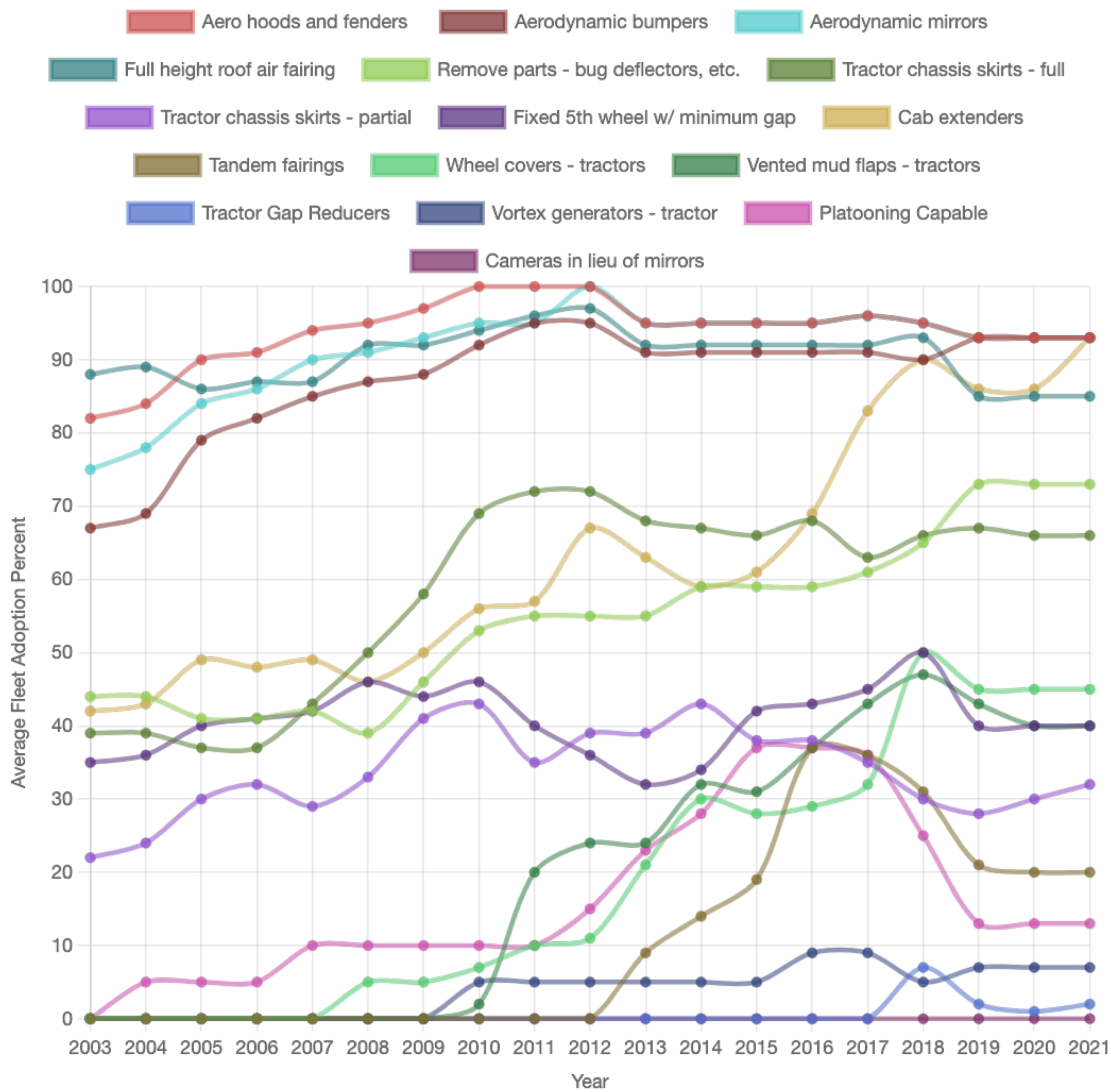
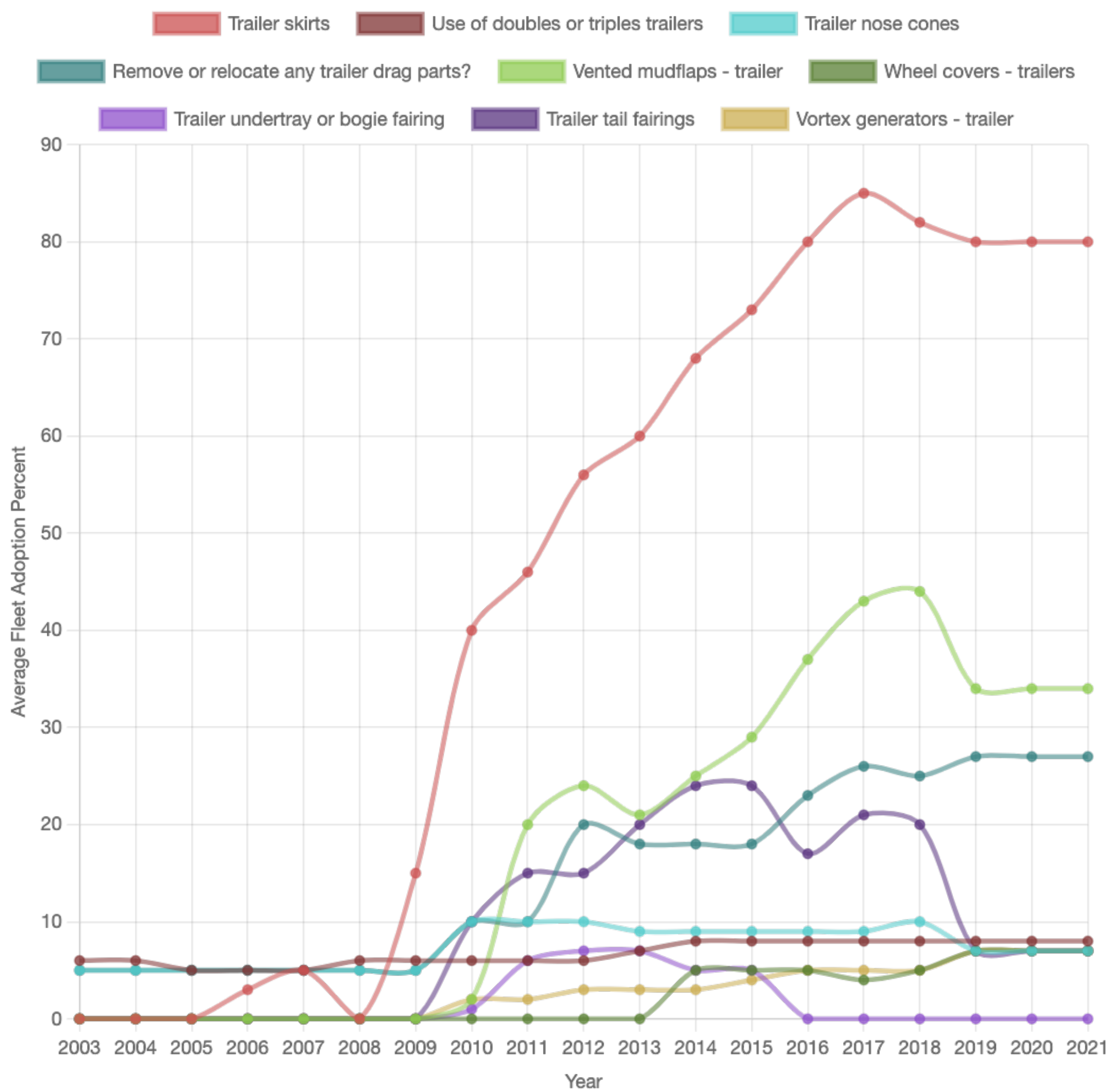


NACFE NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

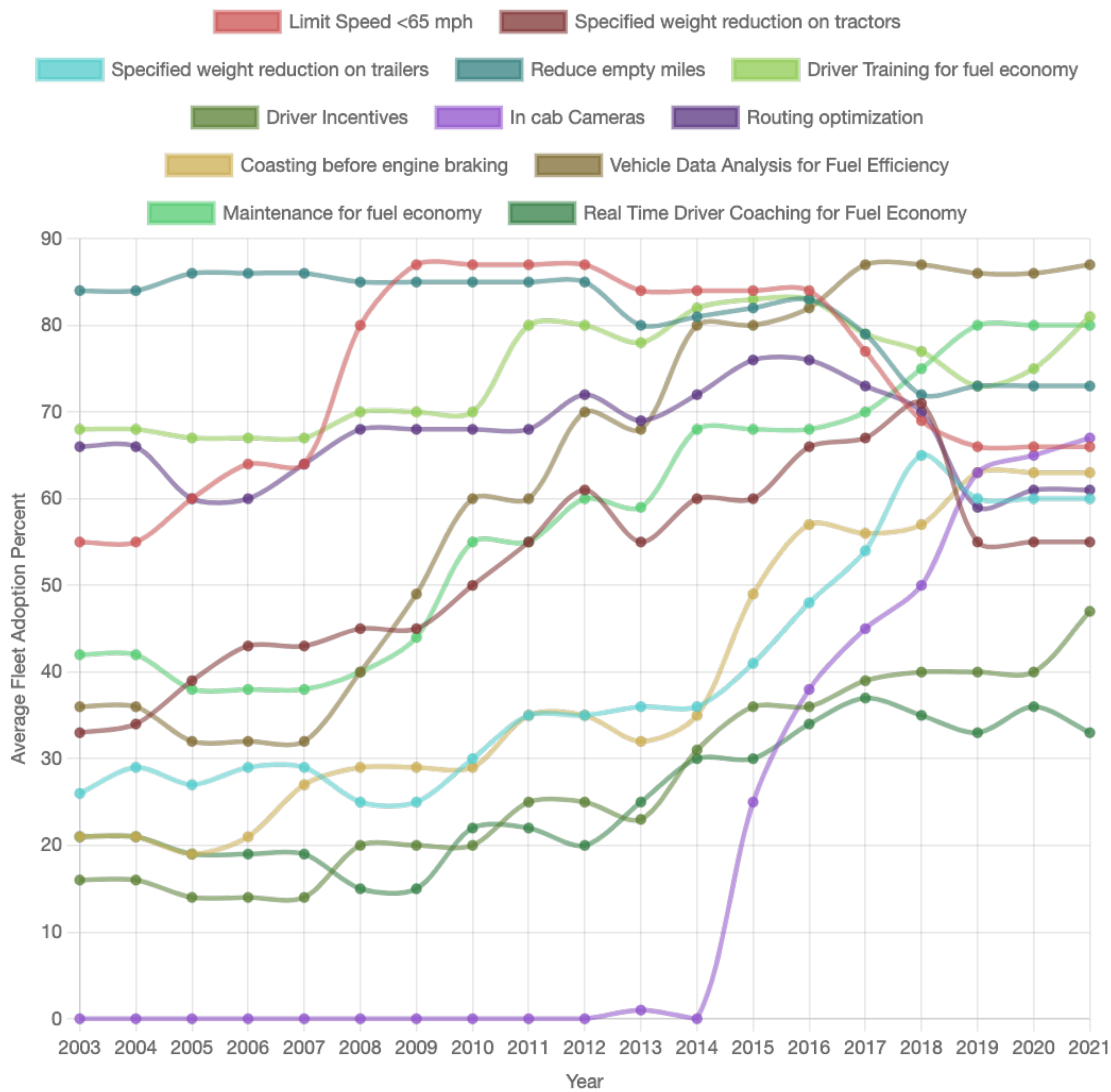
Tractor Aerodynamics



Trailer Aerodynamics



Practices


Limit Speed <65 mph
Specified weight reduction on tractors
Specified weight reduction on trailers
Reduce empty miles
Driver Training for fuel economy
Driver Incentives
In cab Cameras
Routing optimization
Coasting before engine braking
Vehicle Data Analysis for Fuel Efficiency
Maintenance for fuel economy
Real Time Driver Coaching for Fuel Economy
Average Fleet Adoption Percent
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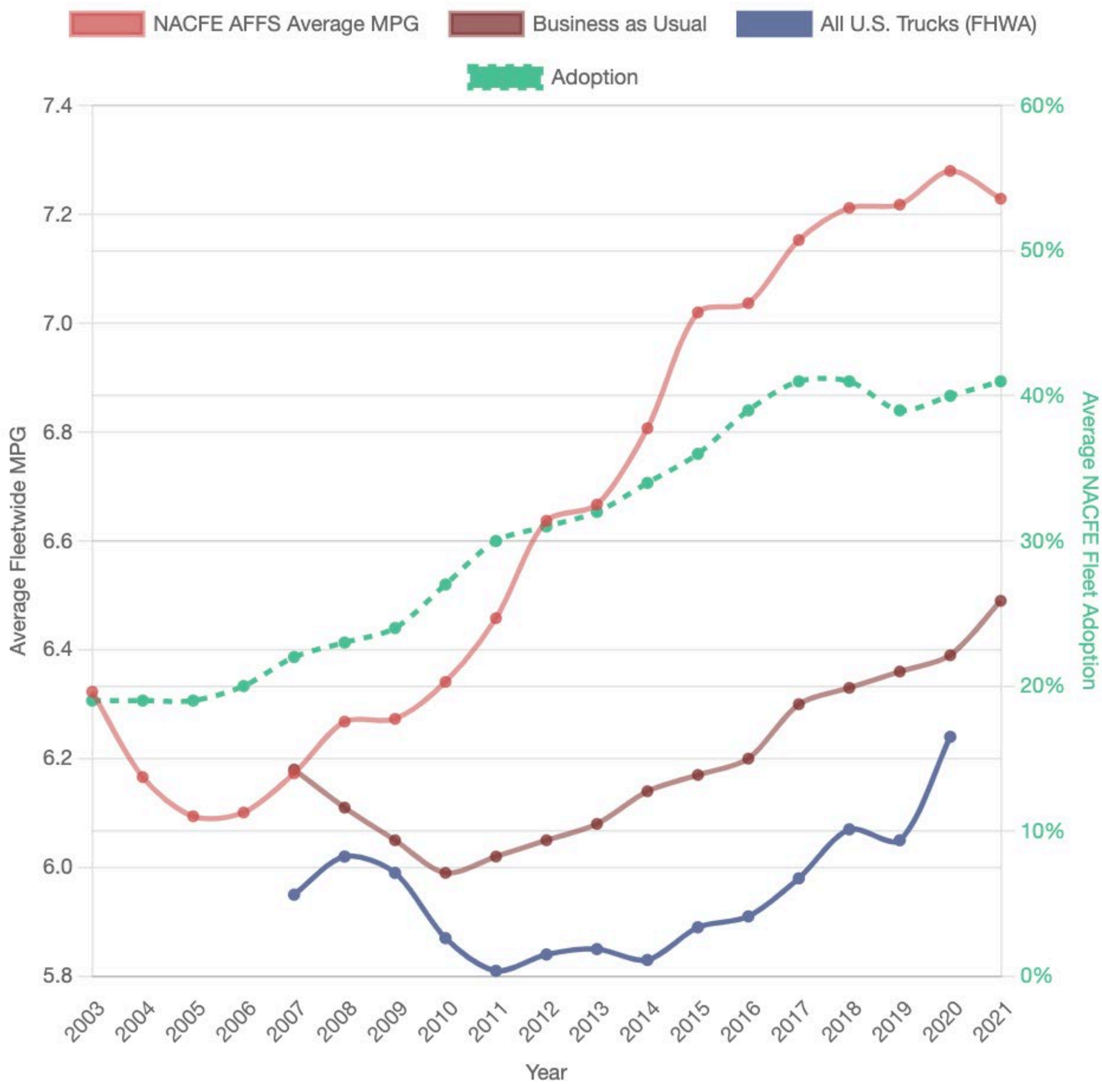
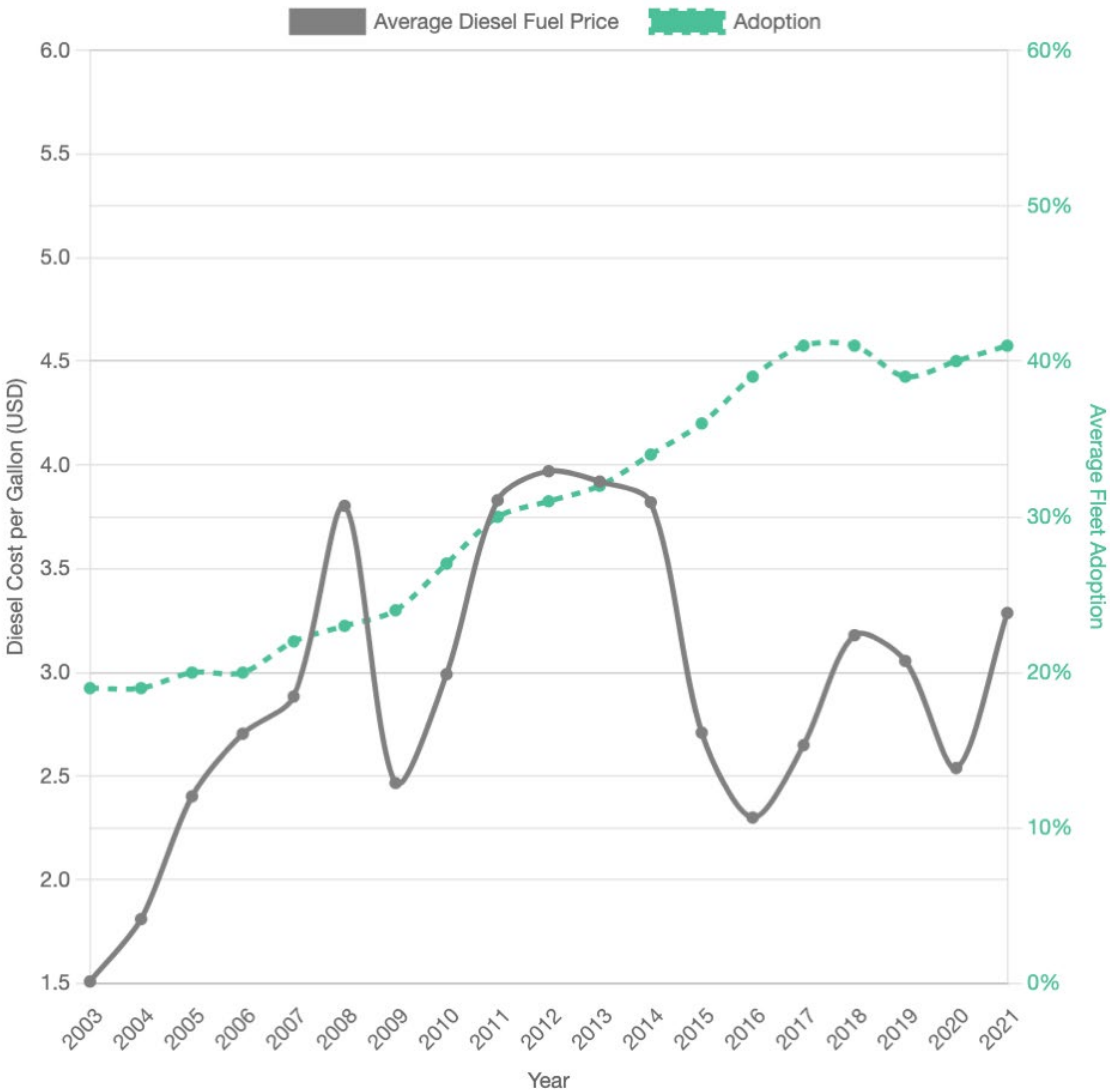
Lightweighting

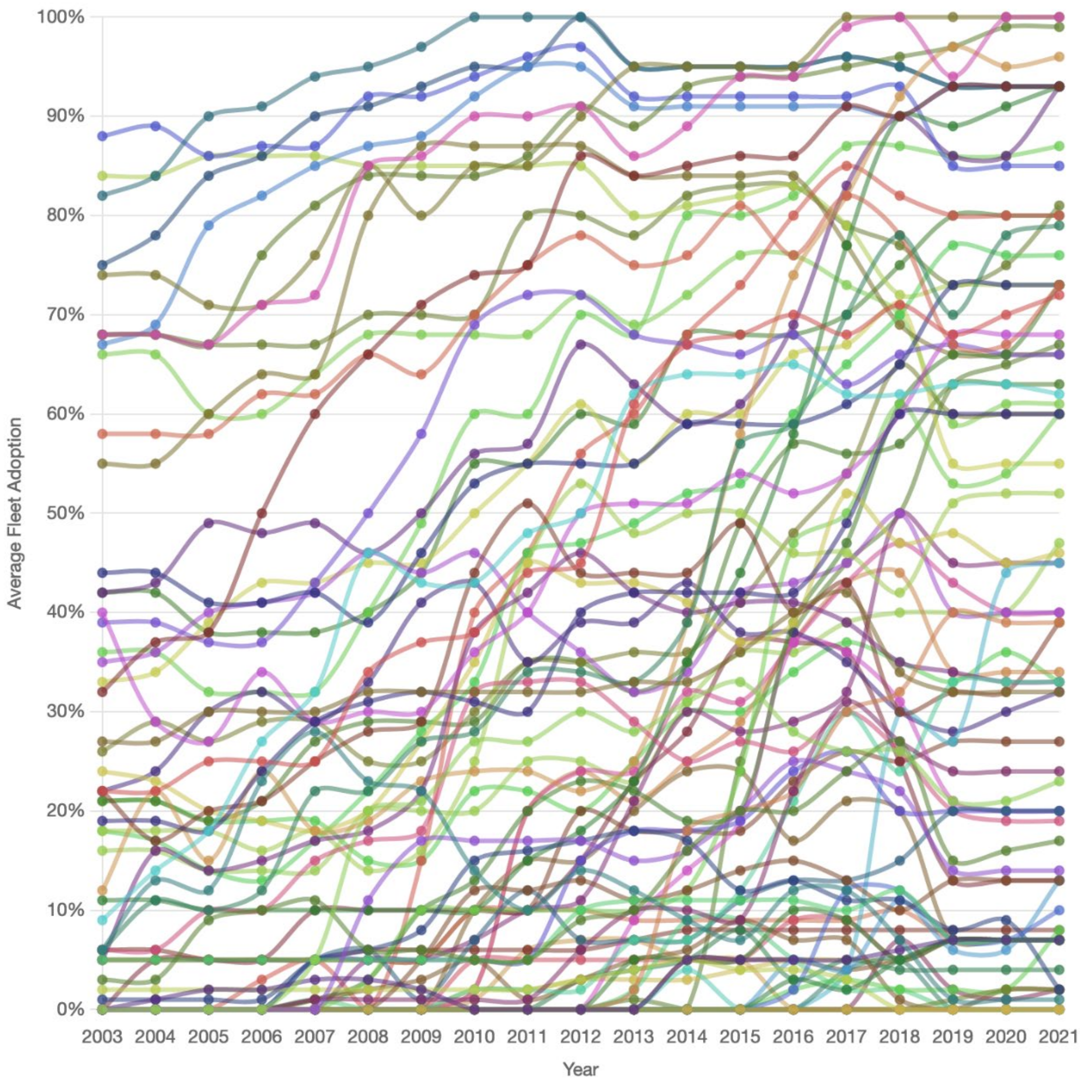
Average Fleetwide MPG



Diesel Cost Per Gallon



Adoption Curves



[View Interactive Chart]