INFORMATION REPORT

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TMC Engine Performance Study

Conducted by TMC's S.3 Engine Study Group

March 2018

Published by the
Technology & Maintenance Council

COUNCIL OF ATA

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COUNCIL OF ATA

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DISCLAIMER

This Information Report is a compilation of maintenance, engineering testing or educational reference data that the Technology & Maintenance Council (TMC) deems useful to the trucking industry. It was developed by TMC's Engine Study Group. It is not a TMC Recommended Practice, and is distributed only for informational purposes. All who use the information contained herein must first satisfy themselves thoroughly that neither the safety of their employees or agents, nor the safety or usefulness of any products, will be jeopardized by any information presented. The following Information Report is not intended nor should it be construed as an endorsement of any particular person, organization, or product.

EXECUTIVE SUMMARY

TMC's "EPA 2007/2010 Engine Report Card" results were based on data from 23 fleets representing 157,541 power units of the U.S. trucking industry. Of these Class 7 and 8 power units, 24 percent were equipped with EPA 2010 engines, 29 percent were equipped with EPA 2007 engines, and 30 percent were equipped with EPA 2004 engines. The survey was administered in November and December 2011 and sent to more than 600 fleets whose representatives held membership in TMC as Fleet Executive level members. The purpose of the survey was to compare the durability, efficiency and costs of EPA 2010 engines with EPA 2007 engines and EPA 2007 engines with EPA 2004 engines by fleet experiences.

TMC's 2016 Mid-Phase 1 Survey results were based on data from 36 fleets representing 48,763 power units of the U.S. trucking industry. Of those Class 7 and 8 power units, 67 percent were equipped with EPA 2014, 2015, and 2016 engines; while 24 percent were equipped with EPA 2010-2013 engines. The survey was sent by email on August 1, 2016 to more than 1,700 fleets from both TMC and ATA members. The purpose of the survey was to:

- assist fleet maintenance executives in their decisions on fleet maintenance costs and expectations in preparing for Phase 2; and;
- determine how the GHG program was progressing for fleets in reducing emissions standards for carbon dioxide (CO_2), oxides of nitrogen (NO_x), and methane (CH_4) as well as control over hydrofluorocarbon (HFC) leaks from air conditioning systems.

The following is summary of the performance benchmarking outcomes from examination of TMC's survey data from 2005 to 2017:

Meets Expectations

- Fuel Economy Performance
- Engine Durability / Reliability
- Aftertreatment Maintenance Intervals
- Particulate Filter Availability
- EGR-Related Component Failure Rates
- DEF Availability, DEF Dispensing / Storage, DEF Consumption
- Driver Satisfaction
- Vehicle Road Breakdowns

Improvement Needed

- Engine Performance
- Engine Maintenance Intervals
- Engine Maintenance Issues
- Aftertreatment Durability / Reliability
- Aftertreatment Maintenance Issues
- Vehicle Out-of-Service Time
- OE Support & Warranty
- Overall Maintenance Cost Difference by Percentage

Unsatisfactory

- Other Emission Component Failure Rates
- Driver Understanding of Aftertreatment System, Driver Understanding of Engine Malfunction Indicators
- Replacement Parts Availability
- Backward Compatibility of Maintenance Components, Requirement for New Maintenance Tools
- Serviceability & Ease of Diagnostics
- Overall Maintenance Costs

INTRODUCTION

The history of heavy-duty commercial vehicle emissions changed substantially in October 1998 when the U.S. Environmental Protection Agency (EPA) and the Department of Justice announced a total settlement that at that time comprised the largest Clean Air Act enforcement action in history.

As part of this action, seven manufacturers of heavy-duty diesel engines agreed to spend more than one billion dollars to settle charges that they illegally poured millions of tons of pollution into the air, including an $83.4 million civil penalty, the largest in environmental enforcement history. The settlement resolved charges that the companies Caterpillar Inc., Cummins Engine Company, Detroit Diesel Corporation, Mack Trucks, Inc., Navistar International Transportation Corporation, Renault Vehicules Industriels, s.a. and Volvo Truck Corporation violated the Clean Air Act by installing devices that defeat emission controls.

The settlement was expected to prevent 75 million tons of nitrogen oxide (NOx) air pollution over the next 27 years; at that time, 75 million was more than the total U.S. NOx emissions for three years. In addition, due to the settlement, the total NOx emissions from diesel engines were to be reduced by one-third as of the year 2003. The settlement was significant because the companies comprised 95 percent of the U.S. heavy-duty diesel engine market.

The complaint alleged that the companies violated the Clean Air Act by selling heavy-duty diesel engines equipped with "defeat devices" — software that altered an engine's pollution control equipment under highway driving conditions. The defeat devices allowed engines to meet EPA emission standards during testing but disabled the emission control system during normal highway driving. The Clean Air Act prohibits any manufacturer from selling any new motor vehicle engine equipped with any device designed to defeat the engine's emission control system. The engines met the emission limits when they run on the EPA's 20-minute Federal Test Procedure, but when the engines are running on the highway, up to three times the limit of NOx emissions resulted.

The companies were alleged to have sold an estimated 1.3 million of the affected engines, which ranged from the type used in tractor-trailers to large pick-up trucks. The affected engines emitted more than 1.3 million tons of excess NOx in 1998 alone, which was six percent of all NOx emissions from cars, trucks and industrial sources in 1998. This was equivalent to the NOx emissions from an additional 65 million cars being on the road. If the companies' use of defeat devices had not been detected and eliminated, more than 20 million tons of excess NOx would have been emitted by the year 2005, according to EPA.

The settlement required that the companies spend collectively over one billion dollars, including $83.4 million in civil penalties, the largest at that time in environmental enforcement history. In addition, EPA estimated that the companies would spend collectively more than $850 million to introduce cleaner new engines, rebuild older engines to cleaner levels, recall pickup trucks that have defeat devices installed and conduct new emissions testing.

Under the agreements lodged in October 1998 with the U.S. District Court for the District of Columbia, the companies were

to reduce significantly emissions from new heavy-duty diesel engines by the end of 1998 and then meet levels beyond what the law required by October 2002. The companies also were to ensure that when older heavy-duty diesel engines are rebuilt, their excess emissions will be reduced. The companies also agreed to move up the date for meeting certain NOx emission standards applicable to non-road engines such as construction equipment. The engines produced became known as the October 2002 "pull-ahead" models.

NOx is one of the six criteria pollutants for which EPA established National Ambient Air Quality Standards. It contributes to the formation of ground level ozone (smog), soot and dust. These pollutants can cause premature death, asthma attacks, bronchitis, and reduced lung functions and other breathing problems, especially in the elderly and children. NOx also causes acid rain, which causes damage to agricultural crops, pollutes drinking water, and causes acid deposition in water bodies.

Manufacturers were subject to additional heavy penalties if they did not meet the agreement deadlines, and were required to demonstrate compliance with the settlement on tests, which supplement the Federal Test Procedure to ensure there were no new defeat devices used.

Impact on Fleets and Equipment Owners

While equipment owners were not directly affected by the consent decree of 1998, their operations were significantly impacted once the new engines were introduced. Three years after the introduction of the post- October 2002 engines, the real cost of industry compliance to new U.S. EPA emissions requirements mandates was clear. Fleets — and the industry — paid a heavy price. The new engine technology, for most manufacturers based on exhaust gas recirculation (EGR), significantly affected performance of heavy- duty diesel engines. The new engines cost more initially, provided lower fuel economy, produced component service life problems from higher underhood heat, are were more costly to maintain and offered reduced resale value.

Evidence to support this was obtained by ATA's Technology & Maintenance Council (TMC) from large fleets who had sufficient data to ensure broad manufacturer representation for any defects. It could be expected that smaller fleets probably shouldered an even higher percentage of the increased costs of operating post-October 2002 engines.

The next phase of emissions regulations impacted the 2007 heavy-duty diesel engines. The 2007 engines, conforming to tighter emissions requirements mandated by the U.S. EPA, were designed to operate on ultra-low sulfur diesel (ULSD) to further reduce NOx and particulate matter through new engine and aftertreatment technology.

For trucking, the benefit in improved air quality came at the price of higher new truck prices, lower fuel economy, additional training and maintenance, and uncertain resale values. The bright side for many fleets however, was an increased level of supplier support — a step up from their experience following the 2002/2004 engine introduction.

EPA's 2007 heavy-duty engine and vehicle standards mandated a 95 percent reduction of NOx as well as a 90 percent reduction in particulate matter (PM). By 2010, after hav-

ing put more than 300,000 miles on tractors, fleet managers were finding out exactly how the 2007 engines really performed — and results varied from better than expected to unacceptable.

In order to achieve the emission limits, the EPA 2007 standard called for a 97 percent reduction in the sulfur content of on-highway diesel fuel. As a result, diesel vehicles were to achieve gasoline-like exhaust emission levels, in addition to their inherent advantages over gasoline vehicles with respect to fuel economy, lower greenhouse gas emissions, and lower evaporative hydrocarbon emissions.

Engine manufacturers employed the use of diesel particulate filter (DPF) technology to reduce particulate matter, as well as other strategies, to comply with the 2007 emission standard. The American Petroleum Institute (API) developed low sulfated ash, phosphorous and sulfur (SAPS) containing engine oils as enablers for the aftertreatments devices such as DPFs.

During this era, the principle driver of new engine technologies was not reliability, durability or even efficiency, but emission reductions. Although air quality in North America benefited greatly because of restrictions on mobile emission sources, fleets had consistently taken a beating through much higher-than-predicted vehicle costs, increased weight, and reliability and durability problems on equipment that grew more complicated and required additional diagnostics and training.

In light of this, TMC's S.3 Engine Study Group decided to survey TMC and ATA members for the purpose of gaining and comparing industry data to explain increased fleet maintenance issues due to increasing stringent emission standards. TMC first made attempts to assess the performance of these post-consent decree engines in 2005 with the fleet survey "Post-October 2002 Diesels: A 300,000 Mile Assessment." Results of this survey were presented at TMC's 2005 Fall Meeting in September 2005. This was followed in 2007 with a TMC technical session on the next generation of engine models, the results of which were presented at TMC's 2008 Annual Meeting in February of that year during a panel discussion entitled, "Industry Scorecard on 2007 Heavy-Duty Diesels . . .First Impressions and Assessments."

In 2010, TMC conducted a followup fleet survey on the performance of EPA 2007-compliant engines, the results of which were presented at TMC's 2010 Annual Meeting in February 2010 during a session entitled, " Fleet Experiences with EPA 2007 Compliant Diesel Engines: A 300,000-Mile Assessment"

In 2011, TMC conducted a third survey — this time on the performance of EPA 2010 engines as compared to EPA 2007 and earlier models. The results were presented during a technical session entitled, "EPA 2007/2010 Engine Report Card" held at TMC's 2012 Annual Meeting in February 2012. This survey rated fleet experiences based on self-reported fuel efficiency and maintenance data, and compared the durability, efficiency and costs of EPA 2010 engines with EPA 2007 engines and EPA 2007 engines with EPA 2004 engines.

Following the EPA 2010 engines, a new approach was taken to address greenhouse gas (GHG) emissions and fuel efficiency stan-

dards for heavy- and medium-duty vehicles. These standards were jointly developed by EPA and NHTSA. NHTSA developed fuel consumption standards under the authority of the 2007 Energy Independence and Security Act (EISA), while the EPA developed a GHG emissions program under the Clean Air Act. The GHG program includes carbon dioxide (CO_2) emission standards, as well as emission standards for oxides of nitrogen (NOx) and methane (CH_4), and provisions to control hydrofluorocarbon (HFC) leaks from air conditioning systems.

The standards were applicable to all on-road vehicles rated at a gross vehicle weight rating more than or equal to 8,500 lbs., and the engines that powered them, except those covered by the GHG emissions and Corporate Average Fuel Economy (CAFE) standards for model year 2012-2016 and model year 2017-2025 light-duty vehicles. The GHG/FE standards were adopted in two phases:

- Phase 1 regulation—adopted on August 9, 2011 —covered model year 2014-2018, with NHTSA fuel economy standards being voluntary in model year 2014-2015 to satisfy EISA lead time requirements.
- Phase 2 regulation—published on August 16, 2016 —applies to Model year 2021-2027 vehicles. The Phase 2 rule also introduced new standards for trailers, a category not previously regulated. The EPA trailer standards begin in model year 2018 (for certain trailers), while NHTSA's standards take effect in model year 2021, with credits available for voluntary participation before then.

Different CO_2 and fuel consumption standards are applicable to different categories of vehicles, including combination tractors, trailers, vocational vehicles, and heavy-duty pickups and vans:

- *Combination tractors:* Phase 1 engine and vehicle standards began in Model year 2014 and were expected to achieve 7-20 percent reduction in CO_2 emissions and fuel consumption by model year 2017 over the 2010 baselines. Phase 2 standards begin in model year 2021 and are expected to achieve 15-27 percent reduction in CO_2 emissions by model year 2027 over the 2017 baselines.
- *Trailers:* The standards start in Model year 2018 and should achieve 6-10 percent reduction in fuel consumption and CO_2 emissions by Model year 2027 over the 2017 baselines.
- *Vocational vehicles:* Phase 1 engine and vehicle standards started in Model year 2014 and should achieve up to a 10 percent reduction in fuel consumption and CO_2 emissions by Model year 2017 over the 2010 baselines. Phase 2 standards start in Model year 2021 and require a 10-18 percent reduction in CO_2 emissions from gasoline vehicles and a 12-24 percent CO_2 emission reduction from diesel vehicles by Model year 2027 over the 2017 baselines.
- *Heavy-duty pickup trucks and vans*: Phase 1 standards started in Model year 2014 and should achieve up to a 10 percent reduction in CO_2 emissions and fuel consumption for gasoline vehicles and 15 percent reduction for diesel vehicles by Model year 2018. Phase 2 standards require a 16 percent CO_2 emissions reduction from Model year 2021 to Model year 2027.

In August 2016, EPA and NHTSA jointly finalized Phase 2 standards for medium- and heavy-duty vehicles from model year 2018

through 2027. During that same time frame, TMC conducted another survey — "EPA/ NHTSA GHG & Fuel Efficiency National Program Mid-Phase 1 Scorecard Survey" — to benchmark against its previous results and reflect upon EPA/NHTSA's Phase 1 regulation to prepare for Phase 2. TMC's 2016 Mid-Phase 1 Survey was applicable through the second year of the four-year Phase 1 regulation and expanded its questionnaire to request additional fleet experiences related exclusively to Phase 1. TMC's Mid-Phase 1 survey final report — *Reported Performance of Mid-Phase 1 2014-2016 EPA/ NHTSA Generation Trucks* — can be found in the **Appendix**. The results were reported February 28 at TMC's 2017 Annual Meeting in Nashville, Tenn.

Performance Benchmarking

This TMC Information Report compares the results of TMC's 2016 EPA/NHTSA GHG & Fuel Efficiency National Program Mid-Phase 1 Scorecard Survey with TMC's previous engine performance surveys from 2005 to 2010.

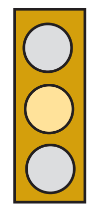
To investigate the extent to which data from TMC's 2011 EPA 2007/2010 Engine Report Card (a summarization of TMC's 2005 to 2010 engine performance surveys) were similar or different from TMC's 2016 "EPA/ NHTSA GHG & Fuel Efficiency National Program Mid-Phase 1 Scorecard Survey," TMC employed benchmarking analytics to discover maintenance and technology trends affecting various aspects of fleet maintenance operations.

More than 30 performance categories were used to assess performance of engines, aftertreatment systems, diesel exhaust fluid (DEF) issues, driver human factors, vehicle availability, service and support. Each category performance had three fleet experience options — 'Better than', 'Same as', and 'Worse than' — that indicated the performance scale of each model year EPA engine.

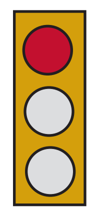
The following rating scales were used to rate each fleet maintenance and technology category:

- *Meets Expectations* — Performance consistently met expectations in most technology responsibilities and at times possibly exceeding expectations.

- *Improvement Needed* — Performance did not consistently meet expectations — performance failed to meet expectations in some technology responsibilities. Recommended practices to improve performance must be planned, including timelines, and monitored to measure progress.



- *Unsatisfactory* — Performance was consistently below expectations in most technology responsibilities, and/or reasonable progress toward critical goals was not made. Significant improvement is needed in maintenance and/or technology practice. Recommended practices to correct performance, including timelines, must be outlined and monitored to measure progress.



SUMMARY OF RESULTS

TMC's "EPA 2007/2010 Engine Report Card" results were based on data from 23 fleets representing 157,541 power units of the U.S. trucking industry. Of these Class 7 and 8 power units, 24 percent were equipped with EPA 2010 engines, 29 percent

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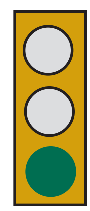
- assist fleet maintenance executives in their decisions on fleet maintenance costs and expectations in preparing for Phase 2; and;
- determine how the GHG program was progressing for fleets in reducing emissions standards for carbon dioxide (CO_2), oxides of nitrogen (NO_x), and methane (CH_4) as well as control over hydrofluorocarbon (HFC) leaks from air conditioning systems.

The observations noted in this Information Report represent 12 years of fleet experience by its participating TMC and/or ATA members.

This survey data, spanning 2005 to 2016, illustrates a repeating pattern of fleet responses that determined 2007 engines were 'Worse than' 2004 engines in 78 percent of maintenance and technology performance categories. This 'Unsatisfactory' result illustrates how industry manufacturers and equipment owners were unprepared for technology change. The data suggests increased fleet costs outweighed fuel efficiency gains or emissions reductions. TMC's 2011 survey also showed how 2010 engines were 'Better than' 2007 engines in 50 percent of maintenance and technology performance categories. Although an impressive growth in fleet maintenance and technology performance, this 'Improvement Needed' rating indicates problems persist for fleets.

The following is summary of the performance benchmarking outcomes from examination of TMC's survey data from 2005 to 2016:

Meets Expectations

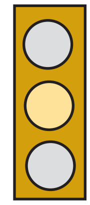


- ***Fuel Economy Performance*** — Data shows an increase in fleet fuel economy based on 2010 to 2016 engines. Fleet experience with fuel economy of 2007 engines was 'Worse than' 2004, however, the 35 percent increase of those responding 'Better than' between 2007 and 2010 engines (highest increase in this study) verify the improvement.
- ***Engine Durability / Reliability*** — Fleet responses show a small increase of engine durability and reliability between Mid-Phase 1 and prior model year engines. This category just meets expectations as per survey definition.
- ***Aftertreatment Maintenance Intervals*** — Mid-Phase 1 engines show more than a five-percent decrease in "Better than" rankings as compared to TMC's 2011 survey. These small 'Better than' increases just meet expectations.
- ***Particulate Filter Availability*** — There was more than a 10-percent increase of favorability in this category

(EPA 14-16 'better than' EPA 10-13 as compared with EPA 10 'better than' EPA 07.)

- ***EGR-Related Component Failure Rates*** — Data shows a 33 percent increase (highest in Study) between 'Better than' fleet response options of the Mid-Phase 1 and prior engines. This is most improved from 2010 engines having the same performance rating as 2007 which was highly rated 'Worse than' 2004 engines.
- ***DEF Availability, DEF Dispensing / Storage, DEF Consumption*** — Fleet responses indicate an improving experience for users of DEF. In all three categories, the 'Better than' fleet experience was chosen by more than 93 percent of fleet participants in TMC's 2016 survey. From the 2011 survey: DEF Availability increased four percent; DEF Dispensing / Storage increased 9.5 percent; and DEF Consumption increased 14.6 percent.
- *Driver Satisfaction* — Data shows that Mid-Phase 1 engines have the same driver satisfaction rate as 2010 engines, which fleets rated 'Better than' 2007. This category, although with a lower percentage in 'EPA14-16 Better than EPA10-13' fleet responses, meets expectations as prior engines show an increasing trend.
- *Vehicle Road Breakdowns* — Mid-Phase 1 engines show an increase in maintenance and technology performance in this category meaning less road breakdowns for fleets. Initially 2007 engines were rated highest in 'Worse than' 2004, then 2010 engines were rated highest in 'Same as' 2007, and since EPA10-13 engines, vehicles with EPA14-16 engines have fewer road breakdowns.

Improvement Needed

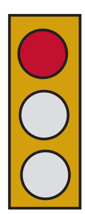


- ***Engine Performance*** — Data shows a near equal fleet response among the three possible choices for Mid-Phase 1 and prior engine models. Fleet experience with engine performance of 2010 engines have increased since 2007 (EPA 07 engines were 25 percent 'Worse than' EPA04), but Mid-Phase 1 engines haven't shown similar progress.
- ***Engine Maintenance Intervals*** — Fleet experience with Mid-Phase 1 engine maintenance intervals are same as 2010 engines which have an increased 'Same as' fleet response to 2007 and 2004 engines. This expresses that engine maintenance intervals have not improved in over a decade.
- ***Engine Maintenance Issues*** — Mid-Phase 1 engines indicate a higher incidence of 'Same as' fleet experience as compared to prior engine models. The EPA10 engines have reported the same experience as 2007, and 2007 had a 65 percent 'Worse than' margin as compared to 2004 engines. EPA 14-16 engines show no better.
- ***Aftertreatment Durability / Reliability*** — TMC's 2011 survey indicated positive results comparing 2007 to 2010 engines, but the 2016 survey indicated little improvement when comparing Mid-Phase 1 engines.
- ***Aftertreatment Maintenance Issues*** — Fleets report Mid-Phase 1 engines perform similarly to prior engines that were rated high from the 2011 Survey. Resulting a lateral growth in technology performance.
- ***Vehicle Out-of-Service Time*** — TMC Mid-Phase 1 Survey participants rated 'EPA14-16 Better than EPA10-13' 10 percent more often than both 'Same

as' and 'Worse than' options; the same results as TMC's 2011 survey with 'EPA10 Better than EPA07.' Based on the modest improvement indicated, this category needs improvement.

- ***OE Support & Warranty*** — Mid-Phase 1 engines are reported to have the same warranty support as prior engines; 2010 engines having the same warranty support as 2007, and 2007 engines 'Same as' 2004. This demonstrates OEMs need better communication with fleet customers.
- ***Overall Maintenance Cost Difference by Percentage*** — Although 2010 engines were rated better than 2007 offerings by a difference of 28 percent, Mid-Phase 1 engines had an average 15 percent positive fleet response rate. This category shows how EPA 07 engines cost 19 percent more to maintain than EPA 04, EPA 10 engines cost 35 percent less to maintain than 2007, and Mid-Phase 1 engines cost 1.3 percent less to maintain than EPA 10-13 engines.

Unsatisfactory



- ***Other Emission Component Failure Rates*** — Data shows a 42 percent difference (highest in the survey comparing EPA 14-16 and EPA 10-13 models) of fleet respondents rating Mid-Phase 1 engines 'Worse than' EPA10-13 engines. TMC's 2011 survey showed that EPA 10 engines had a lower fleet response for 'EPA10 Better than EPA07', but the Mid-Phase 1 Survey proves how emission component failure rates have decreased technology performance.
- ***Driver Understanding of Aftertreatment System, Driver Understanding of Engine Malfunction Indicators*** — Mid-Phase 1 engines are rated highest in 'EPA14-16 Same as EPA10-13' (highest in Study for Driver Understanding of Engine Malfunction Indicators), then EPA 10 engines are mostly rated highest in 'EPA10 Worse than EPA07' (highest in Study for Driver Understanding of Engine Malfunction Indicators). EPA 07 engines are highest rated in 'EPA07 Worse than EPA04' (highest in Study for Driver Understanding of Aftertreatment System). These negatively increasing values enforce the issue of driver training and ensues poor maintenance and technology performance.
- ***Replacement Parts Availability*** — Mid-Phase 1 and prior engine ratings in this study suggest replacement parts availability is a concern for fleets. Few respondents indicate newer models are showing significant improvement in this category.
- ***Backward Compatibility of Maintenance Components, Requirement for New Maintenance Tools*** — Mid-Phase 1 engines are regarded to have the same backward compatibility of maintenance components and requirement for new maintenance tools as prior engines. This relation is to 2010 engines having 'Same as' 2007, and 2007 engines having 'Same as' 2004 (both highest in Study for Backward Compatibility of Maintenance Components). These unchanging adverse trends in industry fleet maintenance continually impact cost of operations.
- ***Serviceability & Ease of Diagnostics*** — Fleet respondents rated EPA14-16 engines 'Same as' EPA10-13 higher than other options, although 'Worse than' was a close second. This result, as well as 2010 engines rated 'Worse

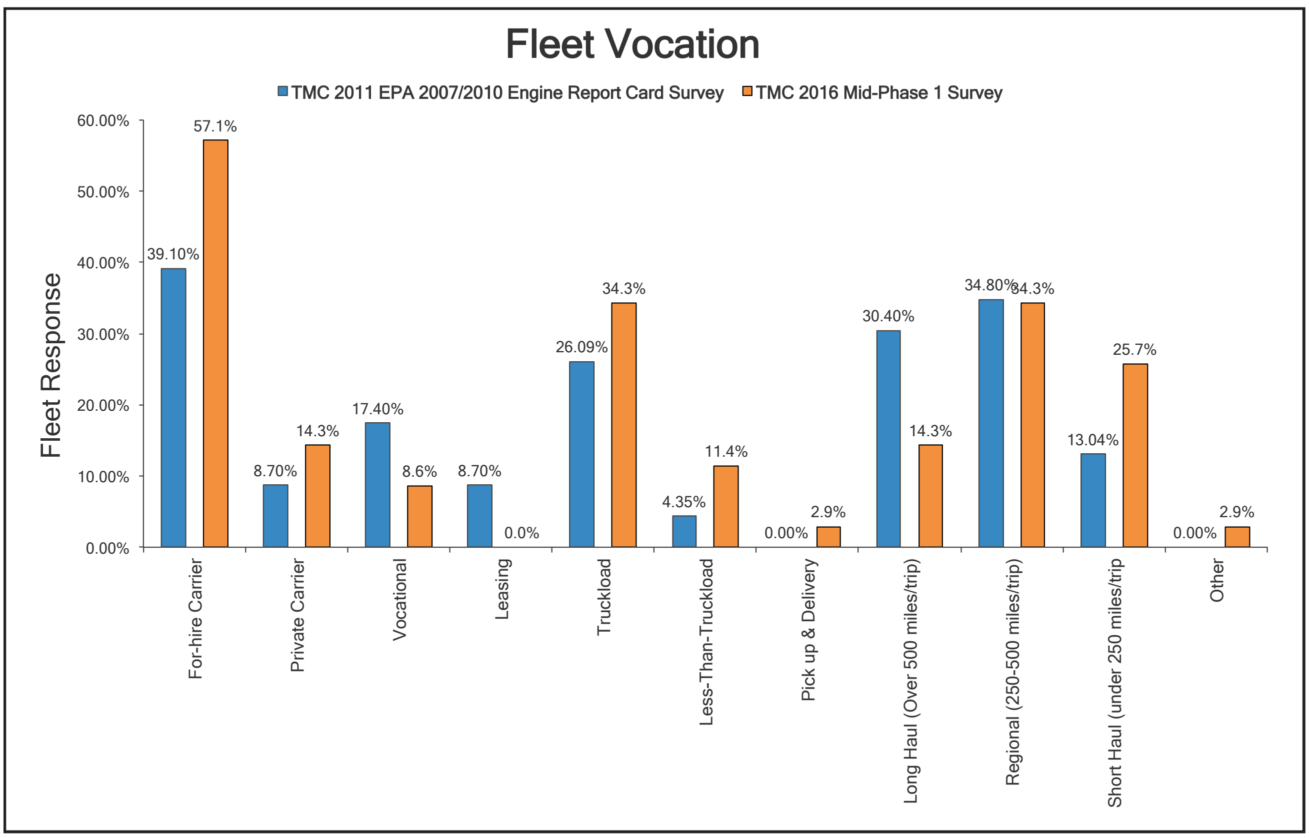
SUMMARY OF RESULTS

than' 2007 — which were rated 'Worse than' 2004 — indicates serviceability and ease of diagnostics to be unsatisfactory to fleet expectations.

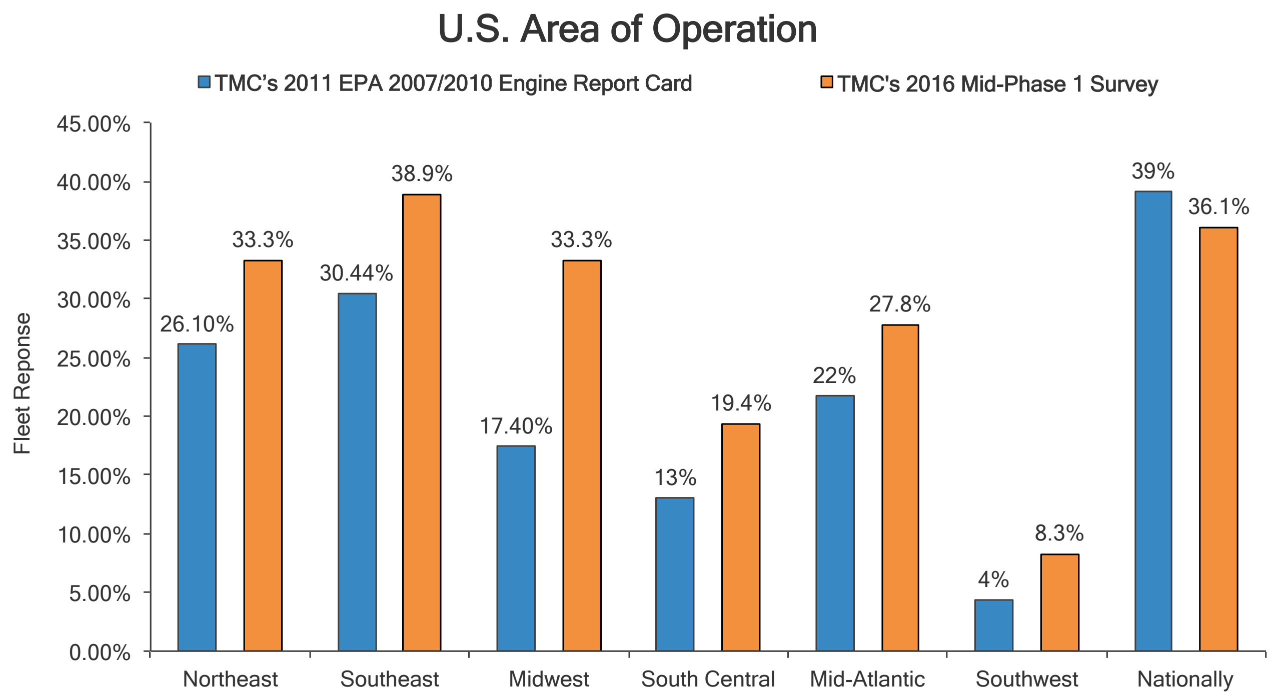
- *Overall Maintenance Costs* — TMC's 2016 survey was one respondent away from having 'EPA14-16 Worse than EPA10-13' to equal the 'Better than' option. The 2011 survey rated 2010 engines 'Worse than' 2007 — which were also rated 'Worse than' 2004 engines. Not much has changed for fleet maintenance costs from the impact of 2007 engines in close to a decade.

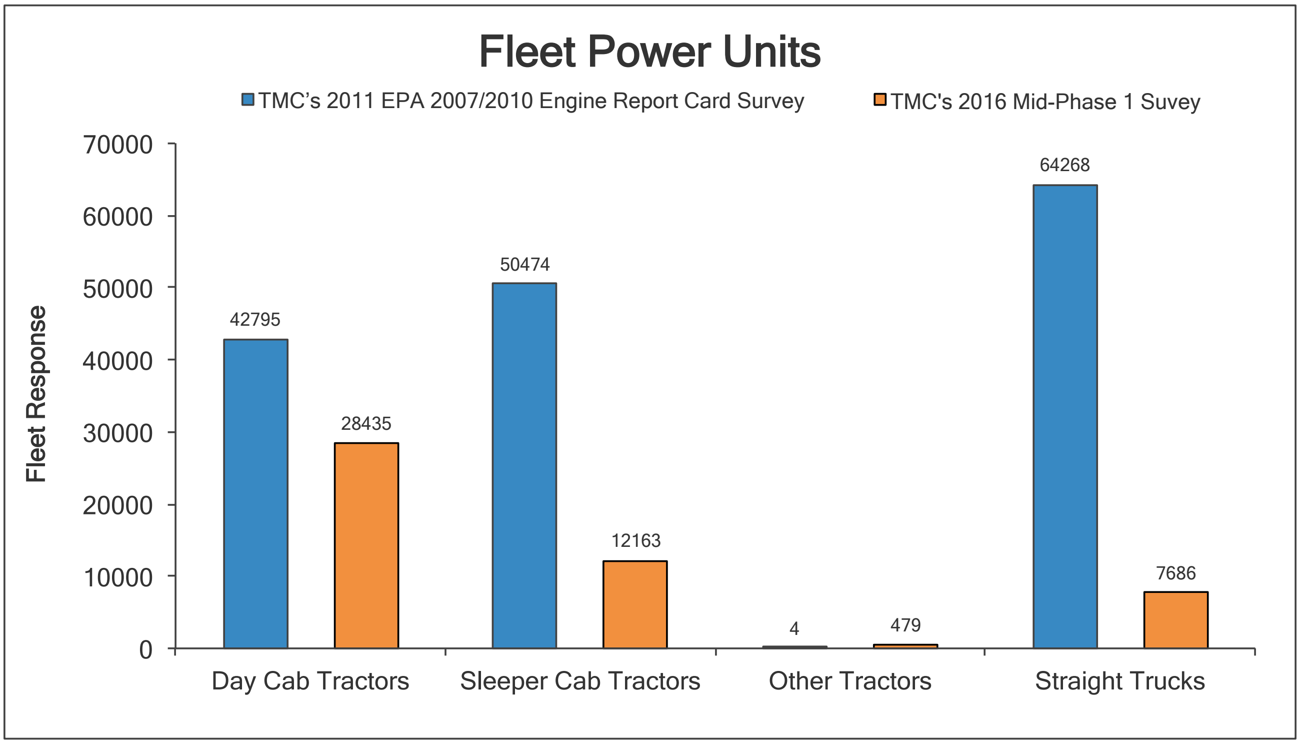
DATA CHARTS

The following charts compare key data findings between TMC's 2011 EPA 2007/2010 Engine Report Card and TMC's 2016 EPA/NHTSA GHG & Fuel Efficiency National Program Mid-Phase 1 Scorecard Survey:

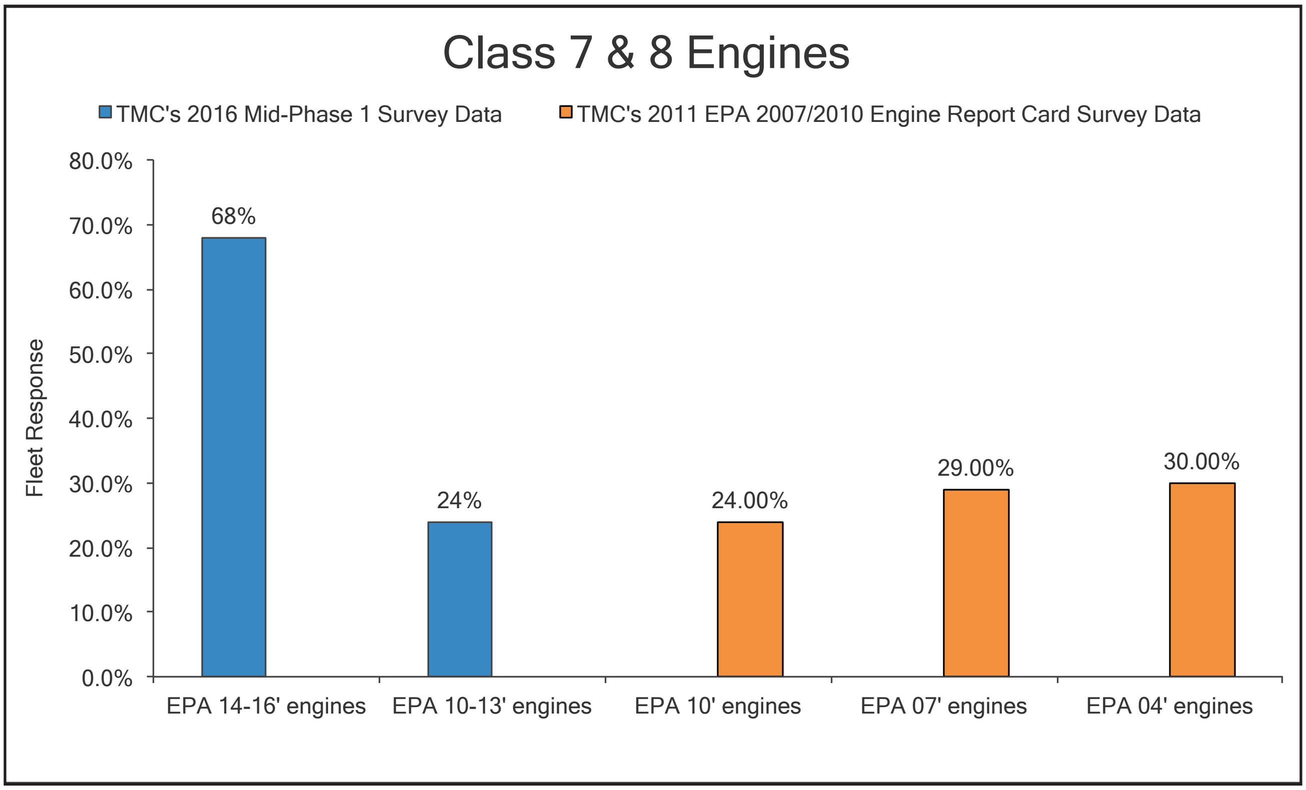


DATA CHARTS

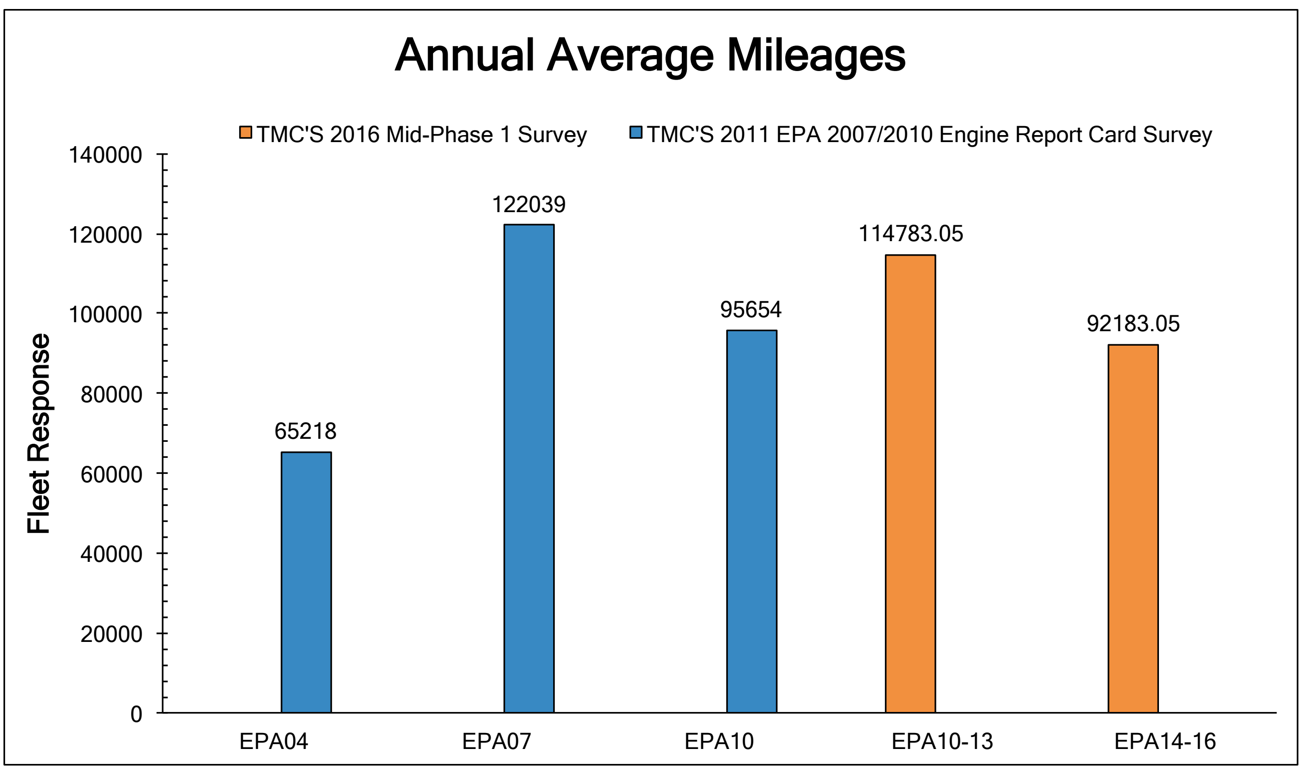

U.S. Area of Operation
TMC's 2011 EPA 2007/2010 Engine Report Card
TMC's 2016 Mid-Phase 1 Survey
Fleet Reponse
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
26.10%
33.3%
30.44%
38.9%
17.40%
33.3%
13%
19.4%
22%
27.8%
4%
8.3%
39%
36.1%
Northeast
Southeast
Midwest
South Central
Mid-Atlantic
Southwest
Nationally


Fleet Power Units
TMC's 2011 EPA 2007/2010 Engine Report Card Survey
TMC's 2016 Mid-Phase 1 Suvey
Fleet Response
70000
60000
50000
40000
30000
20000
10000
0
42795
28435
50474
12163
4
479
64268
7686
Day Cab Tractors
Sleeper Cab Tractors
Other Tractors
Straight Trucks

DATA CHARTS



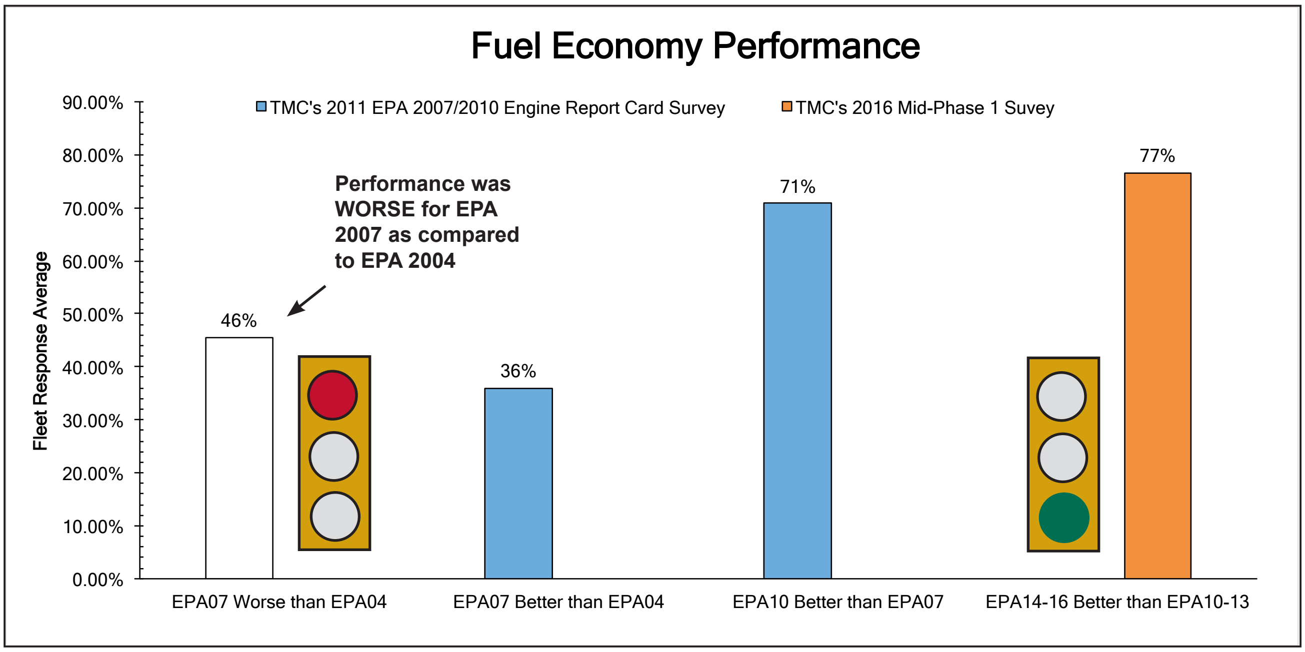
Class 7 & 8 Engines
TMC's 2016 Mid-Phase 1 Survey Data
TMC's 2011 EPA 2007/2010 Engine Report Card Survey Data
Fleet Response
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
68%
24%
24.00%
29.00%
30.00%
EPA 14-16' engines
EPA 10-13' engines
EPA 10' engines
EPA 07' engines
EPA 04' engines

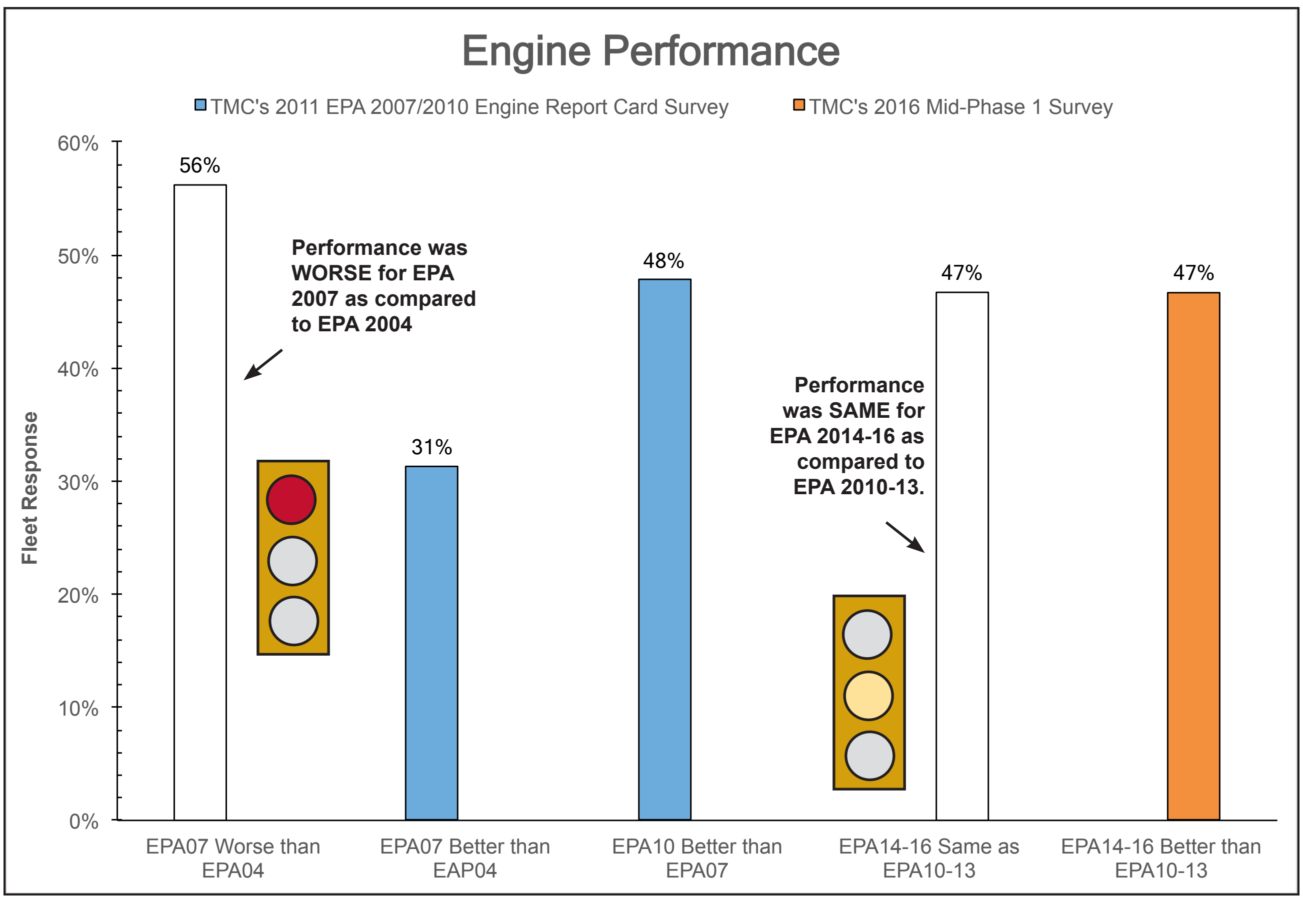


Annual Average Mileages
TMC'S 2016 Mid-Phase 1 Survey
TMC'S 2011 EPA 2007/2010 Engine Report Card Survey
Fleet Response
140000
120000
100000
80000
60000
40000
20000
0
65218
122039
95654
114783.05
92183.05
EPA04
EPA07
EPA10
EPA10-13
EPA14-16

DATA CHARTS

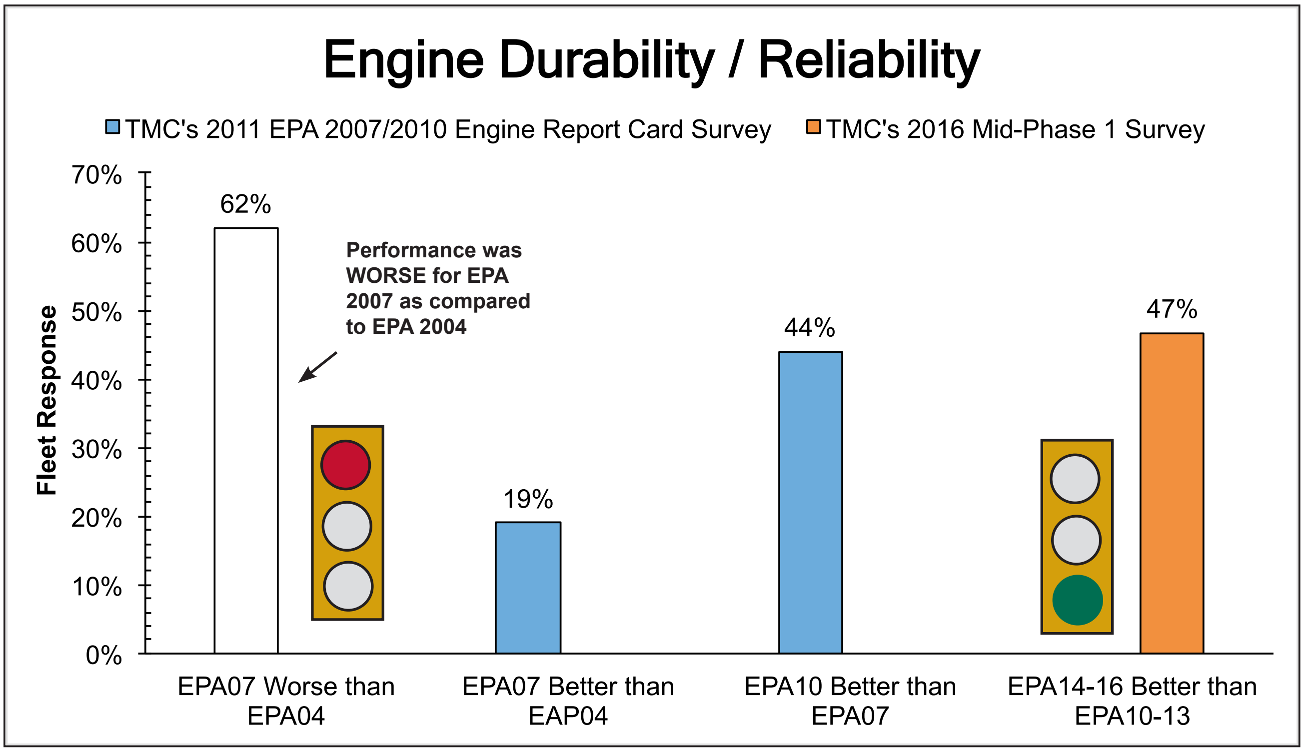
NOTE: Patterns are applied to the column bars in the graph below indicate the performance of that generation equipment is the same or worse than that of the previous generation or generations.

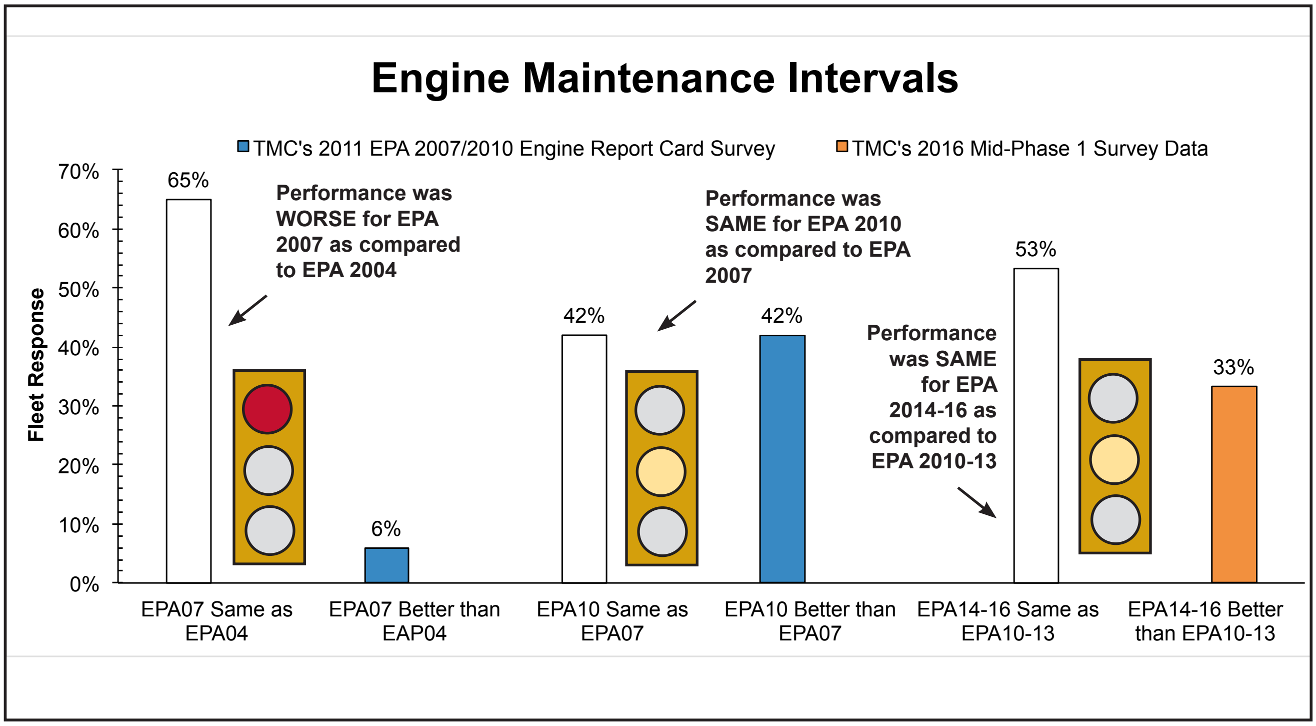




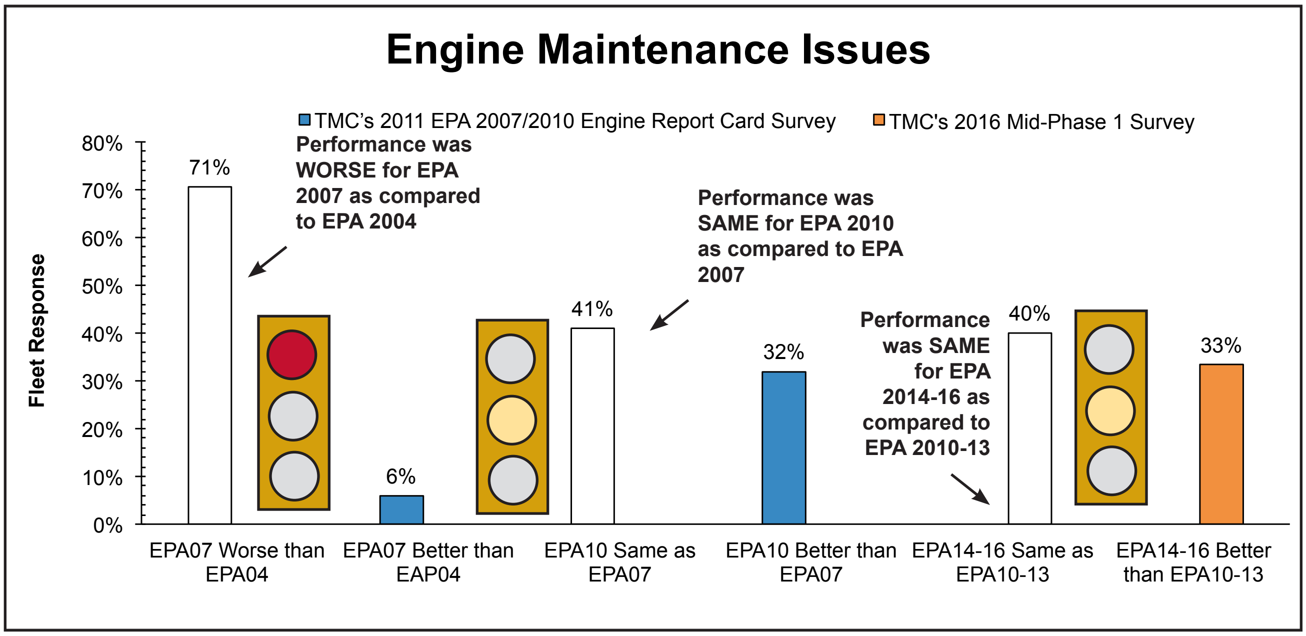
DATA CHARTS

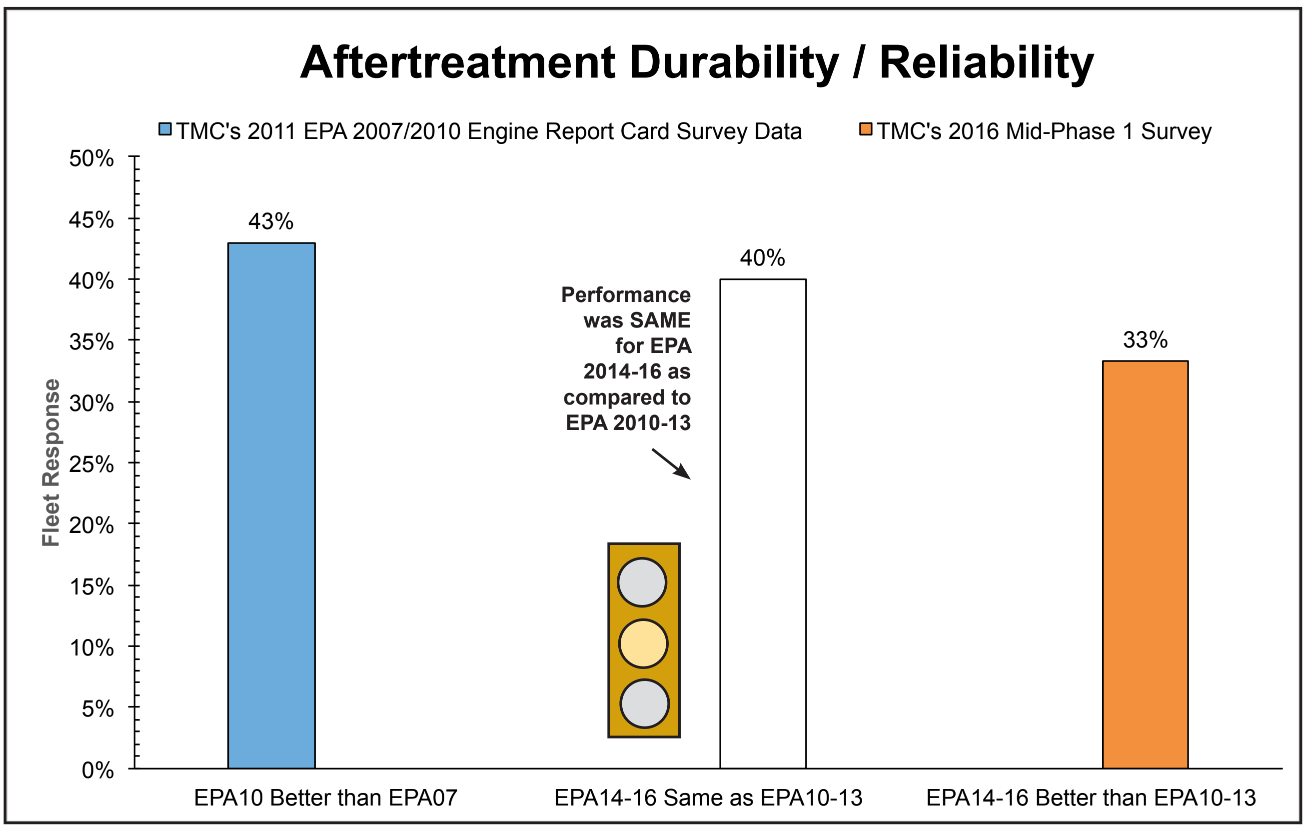
NOTE: Patterns are applied to the column bars in the graph below indicate the performance of that generation equipment is the same or worse than that of the previous generation or generations.





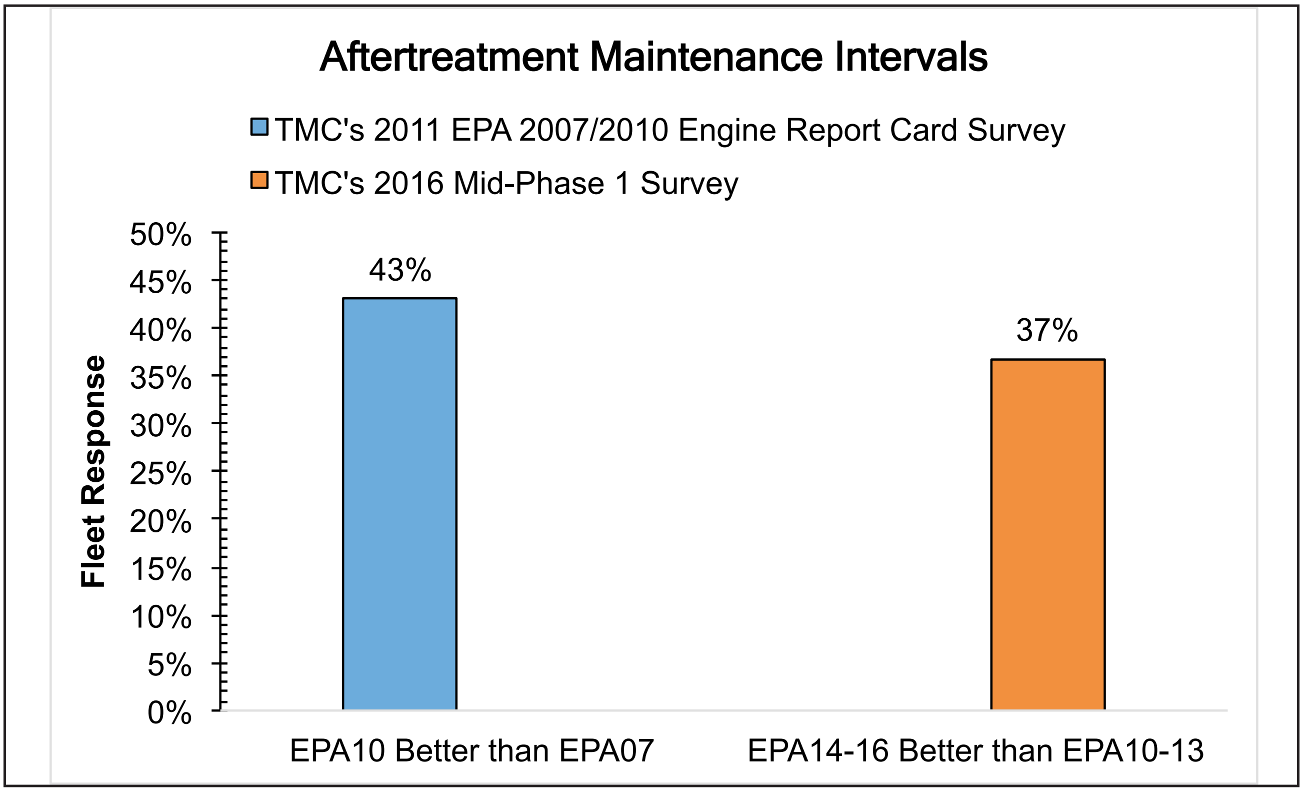
NOTE: Patterns are applied to the column bars in the graph below indicate the performance of that generation equipment is the same or worse than that of the previous generation or generations.

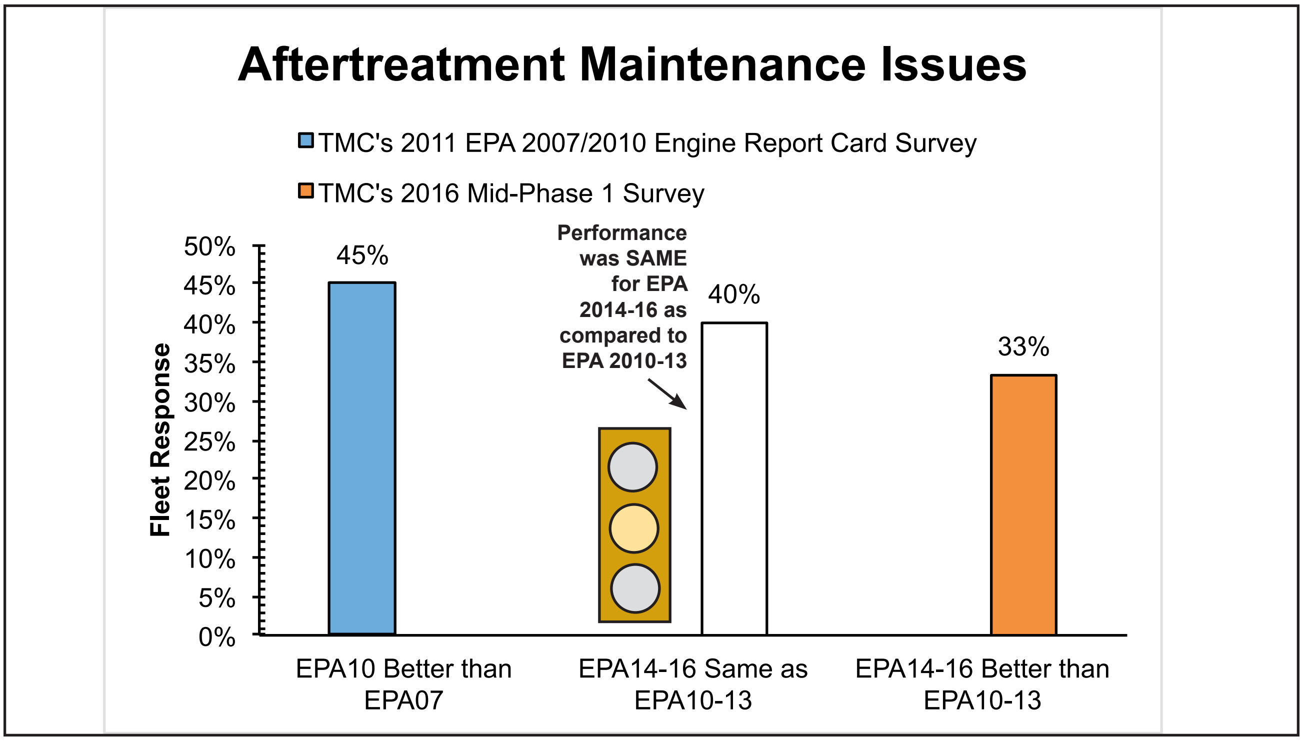




DATA CHARTS

NOTE: Patterns are applied to the column bars in the graph below indicate the performance of that generation equipment is the same or worse than that of the previous generation or generations.





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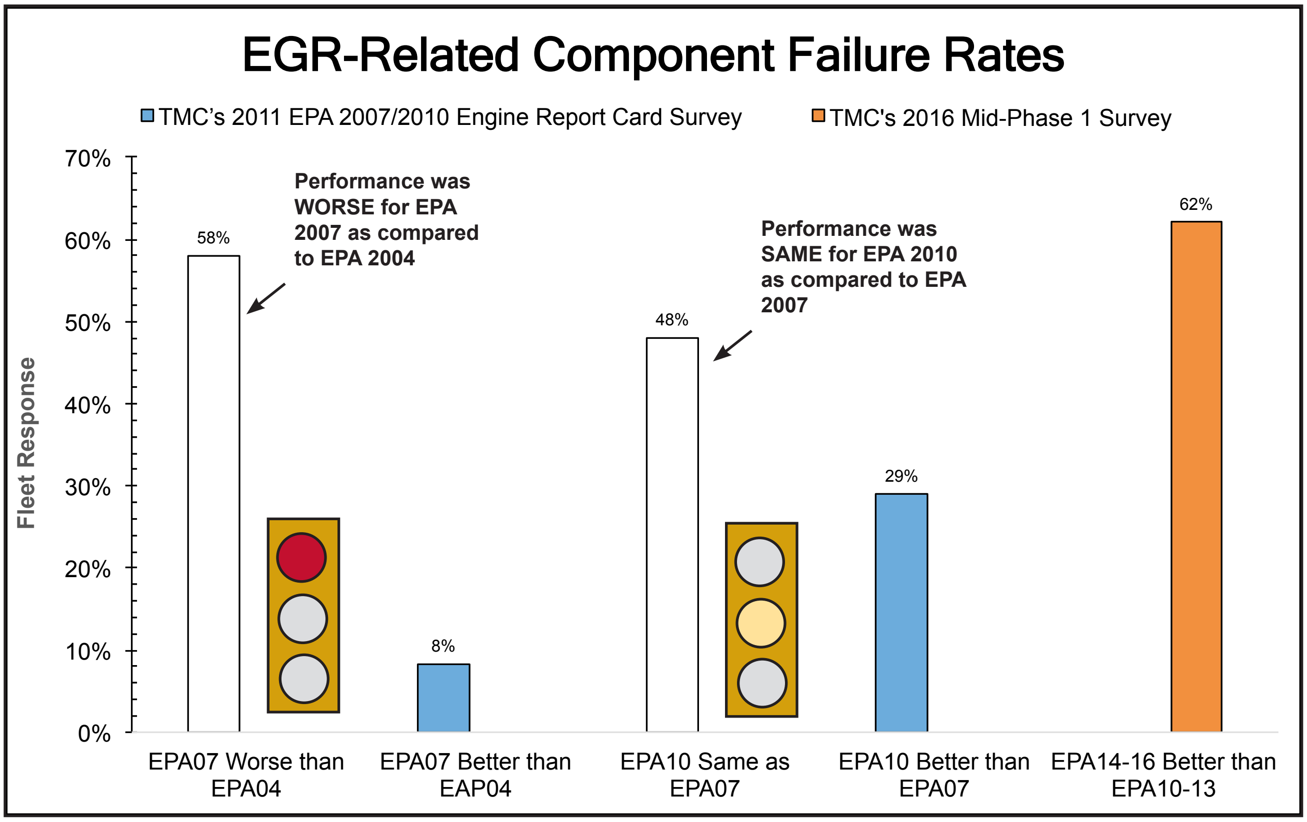
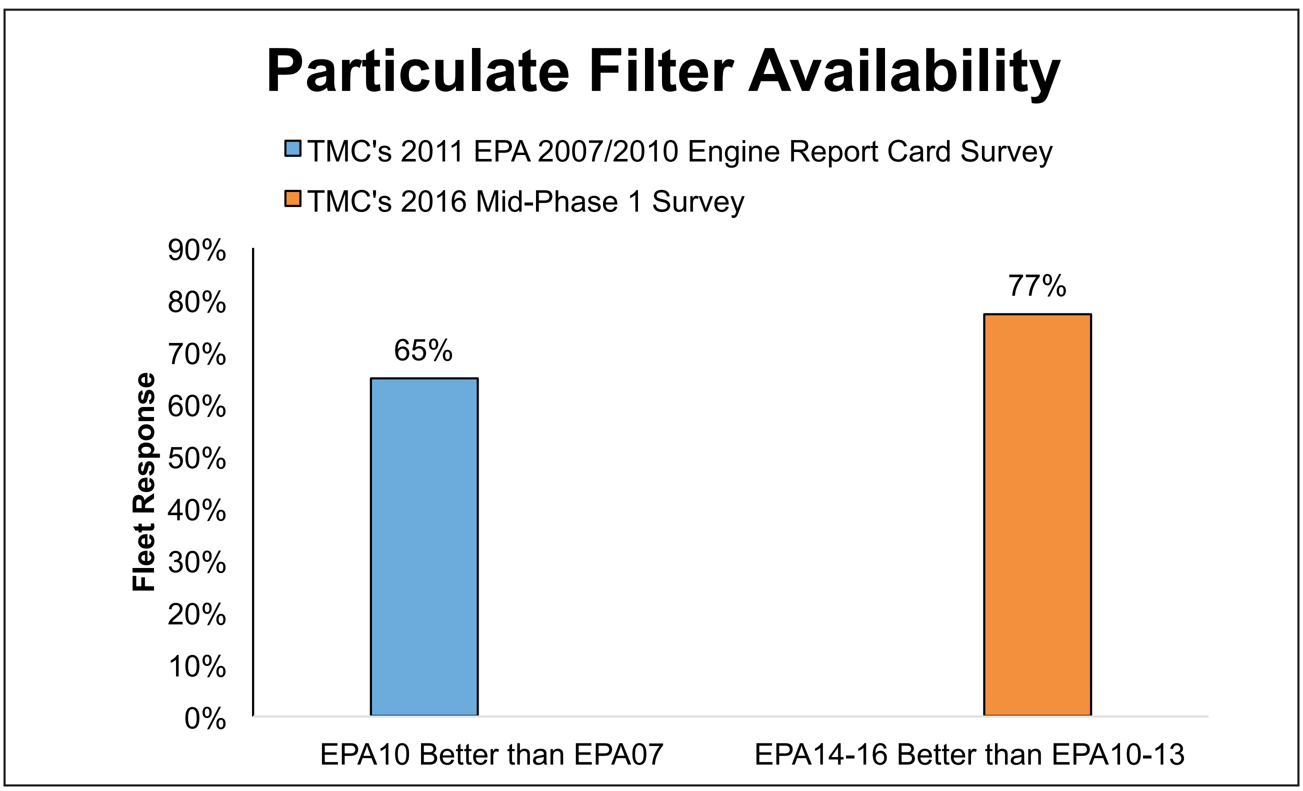
NOTE: Patterns are applied to the column bars in the graph below indicate the performance of that generation equipment is the same or worse than that of the previous generation or generations.





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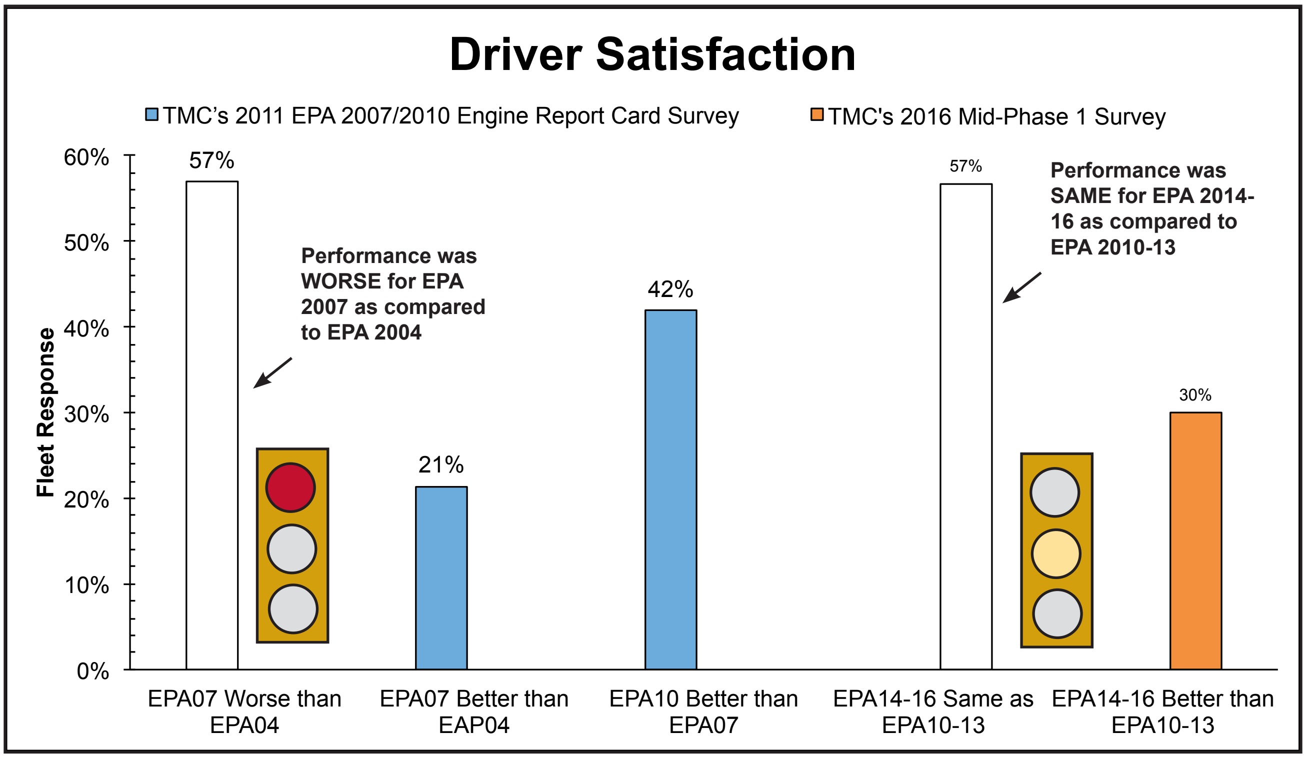
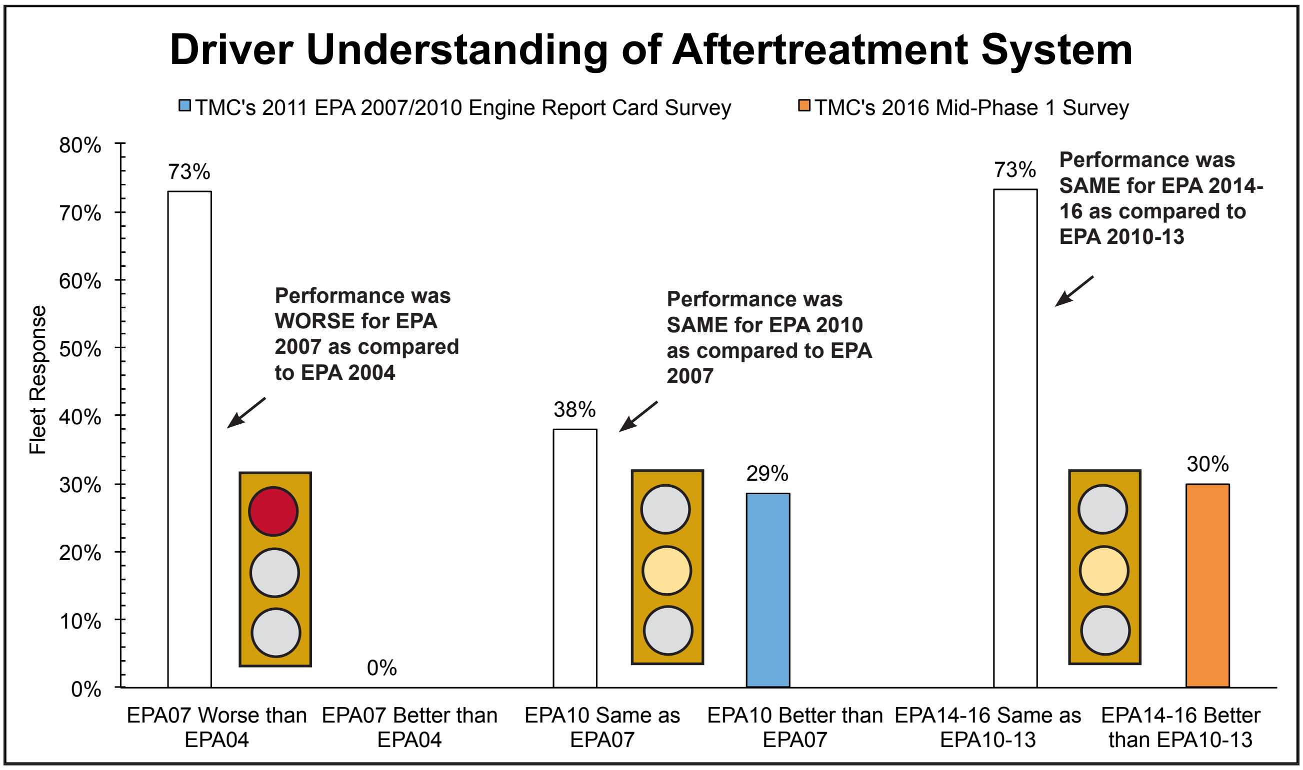
NOTE: Patterns are applied to the column bars in the graph below indicate the performance of that generation equipment is the same or worse than that of the previous generation or generations.





DATA CHARTS

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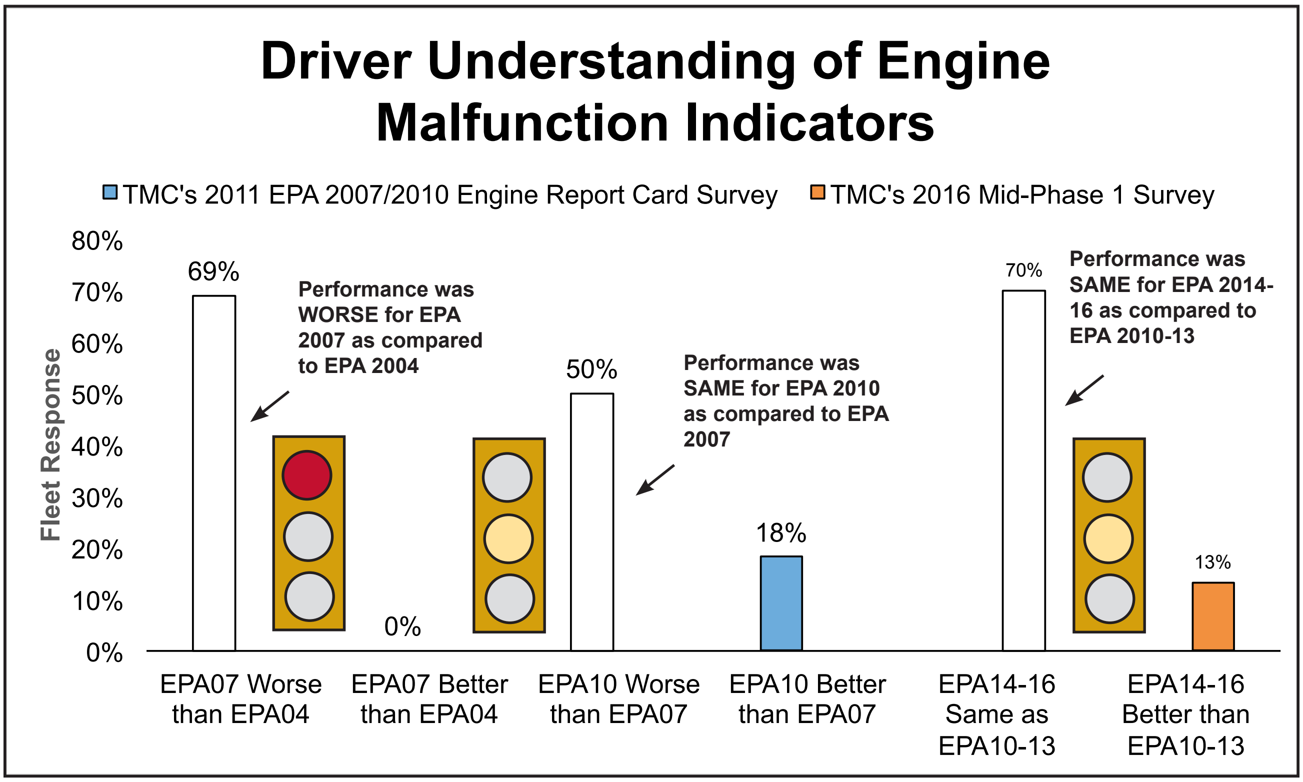

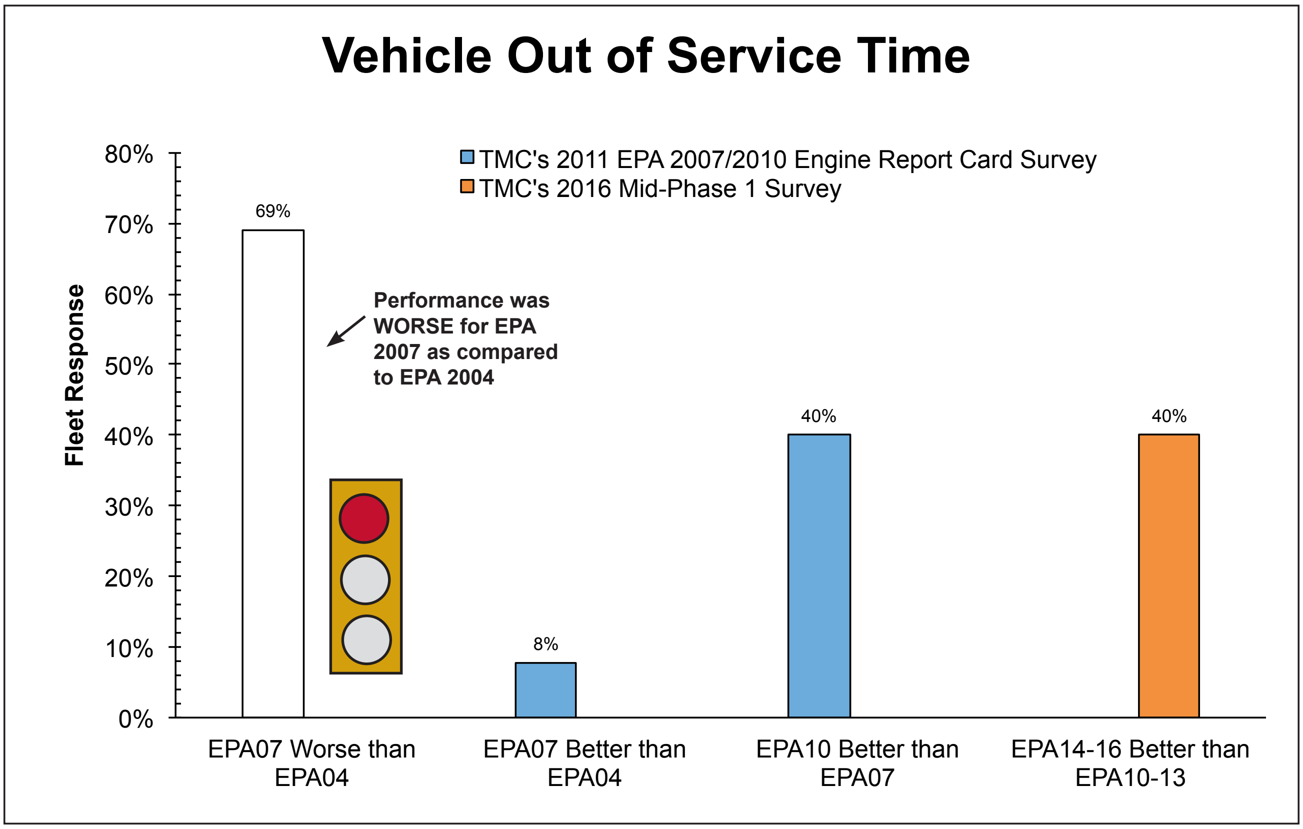

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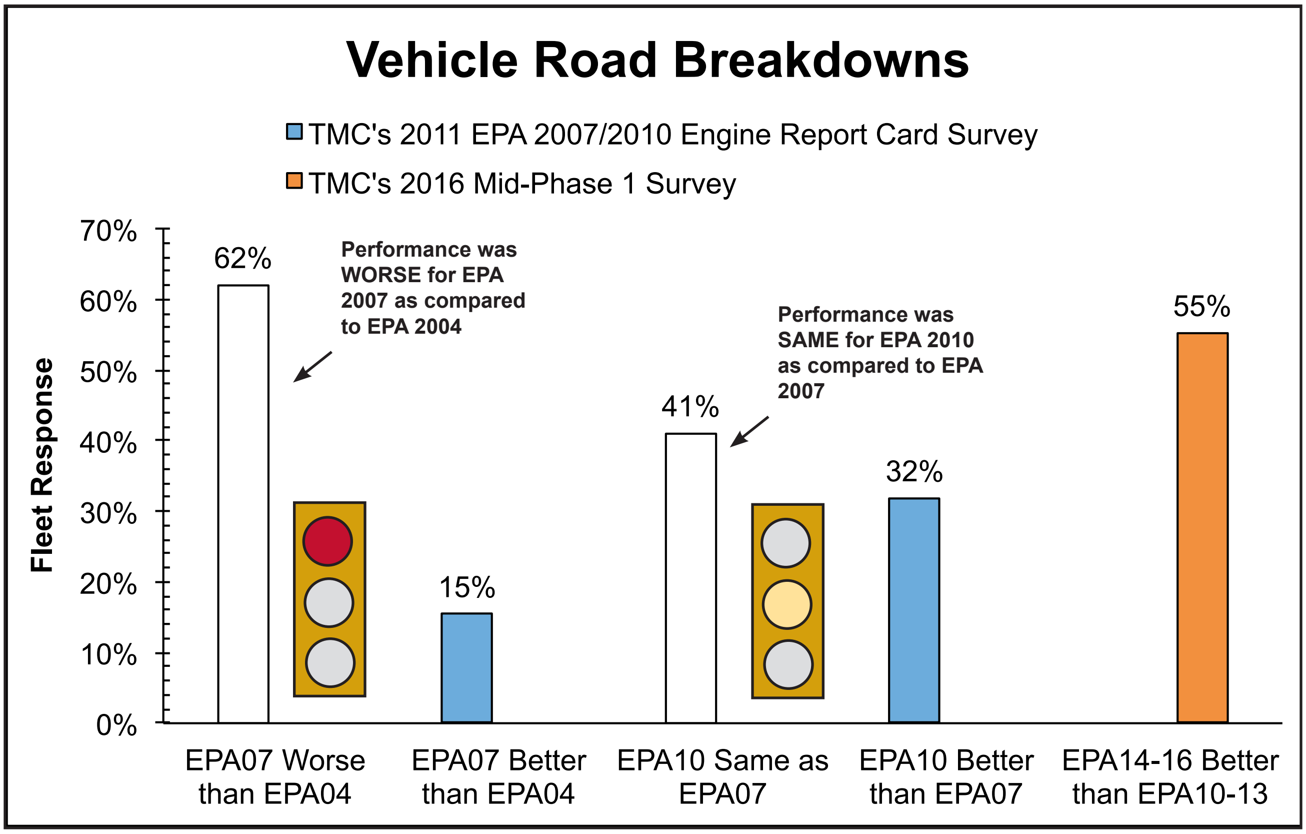
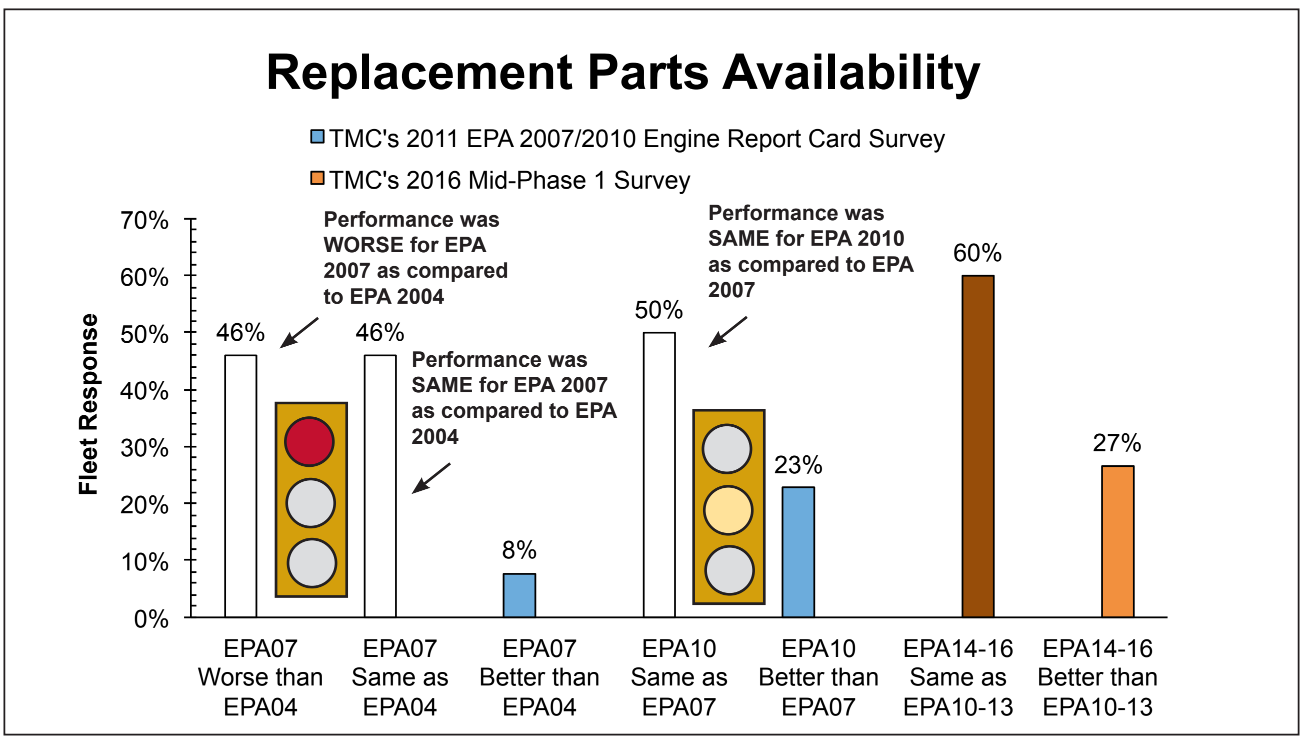
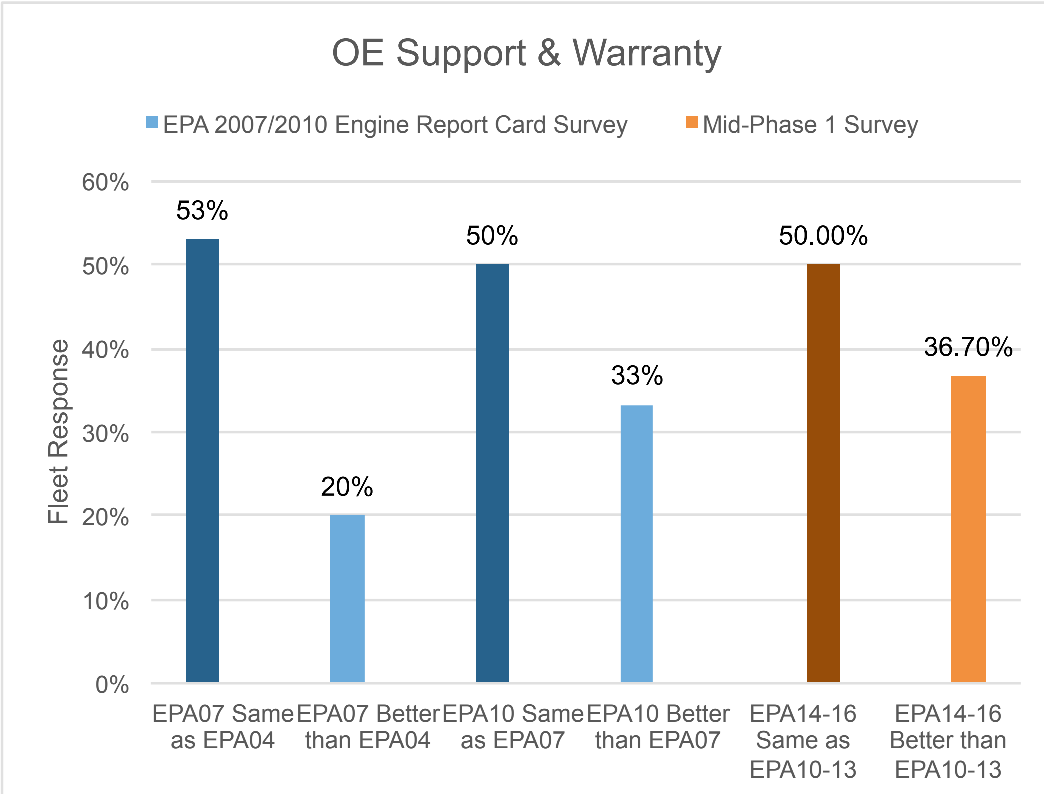
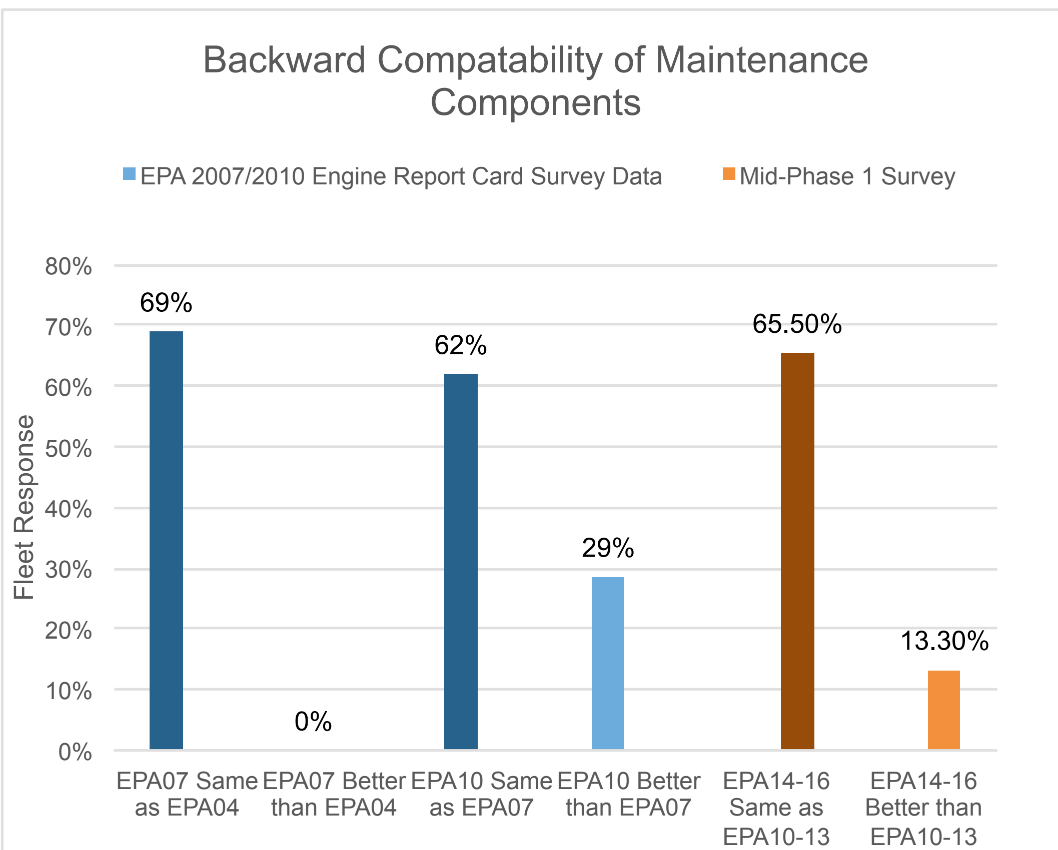
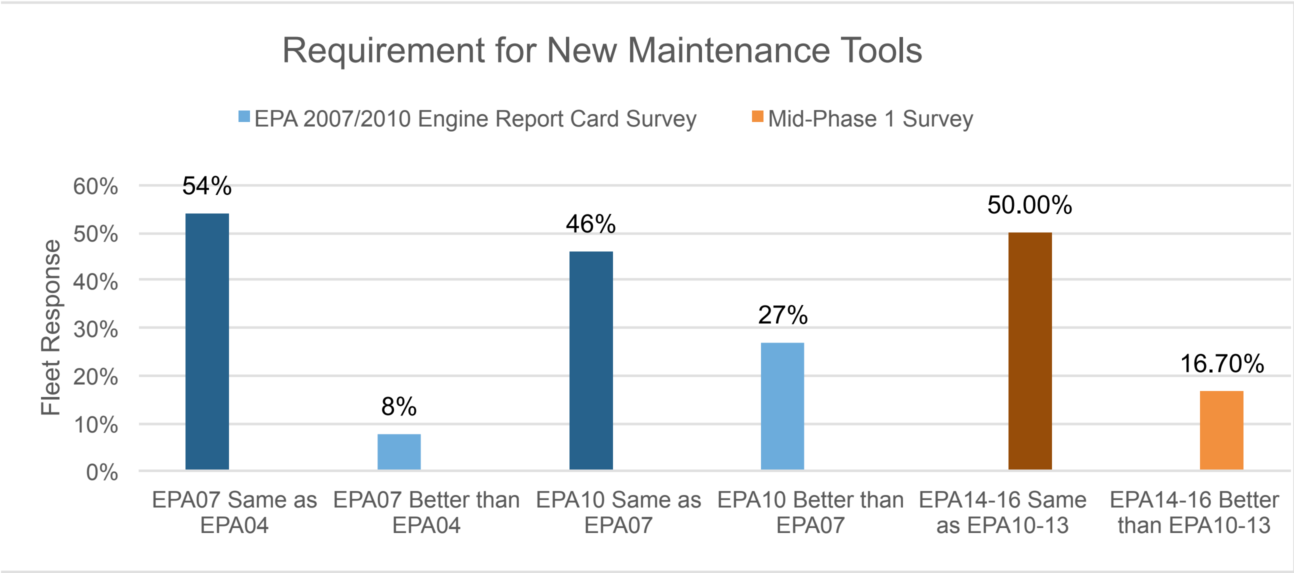




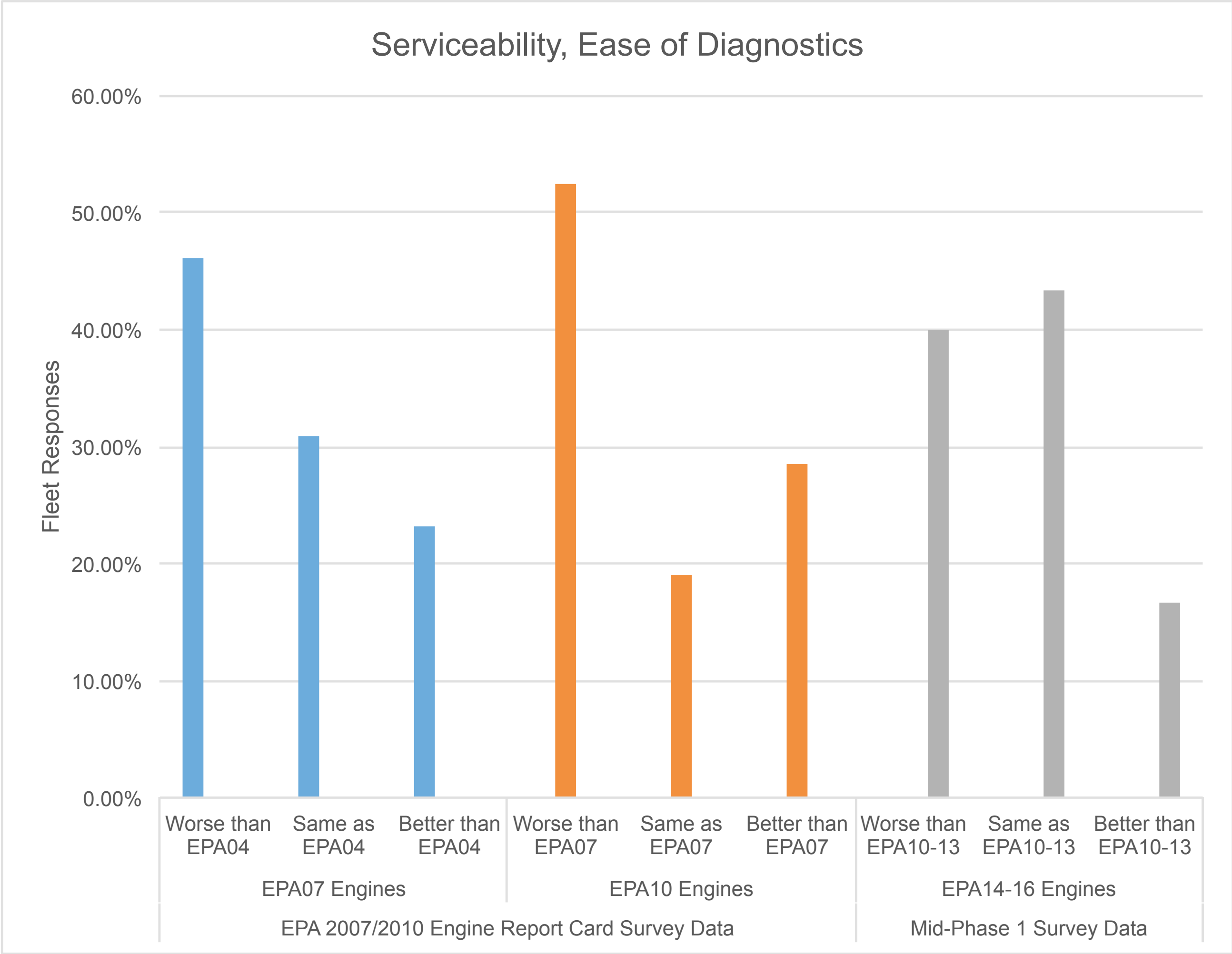

OE Support & Warranty
EPA 2007/2010 Engine Report Card Survey
Mid-Phase 1 Survey
Fleet Response
60%
50%
40%
30%
20%
10%
0%
53%
20%
50%
33%
50.00%
36.70%
EPA07 Same as EPA04
EPA07 Better than EPA04
EPA10 Same as EPA07
EPA10 Better than EPA07
EPA14-16 Same as EPA10-13
EPA14-16 Better than EPA10-13


Backward Compatability of Maintenance Components
EPA 2007/2010 Engine Report Card Survey Data
Mid-Phase 1 Survey
Fleet Response
80%
70%
60%
50%
40%
30%
20%
10%
0%
69%
0%
62%
29%
65.50%
13.30%
EPA07 Same as EPA04
EPA07 Better than EPA04
EPA10 Same as EPA07
EPA10 Better than EPA07
EPA14-16 Same as EPA10-13
EPA14-16 Better than EPA10-13

DATA CHARTS

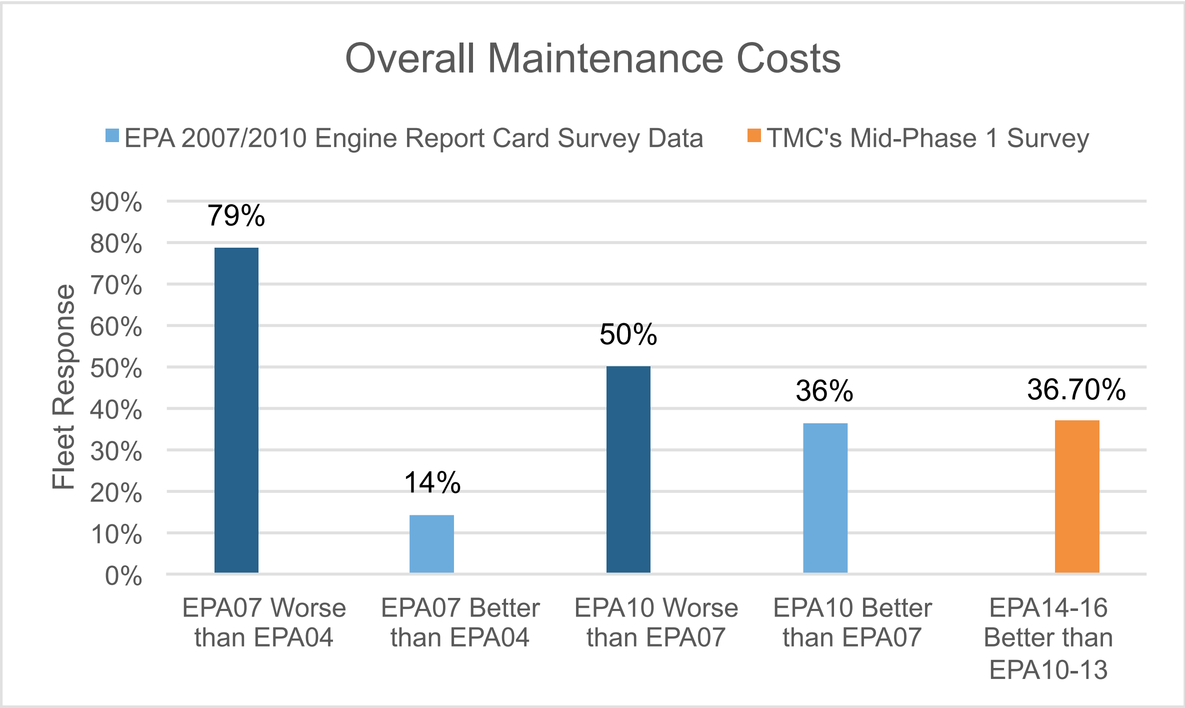


Requirement for New Maintenance Tools
EPA 2007/2010 Engine Report Card Survey
Mid-Phase 1 Survey
Fleet Response
60%
50%
40%
30%
20%
10%
0%
54%
8%
46%
27%
50.00%
16.70%
EPA07 Same as EPA04
EPA07 Better than EPA04
EPA10 Same as EPA07
EPA10 Better than EPA07
EPA14-16 Same as EPA10-13
EPA14-16 Better than EPA10-13

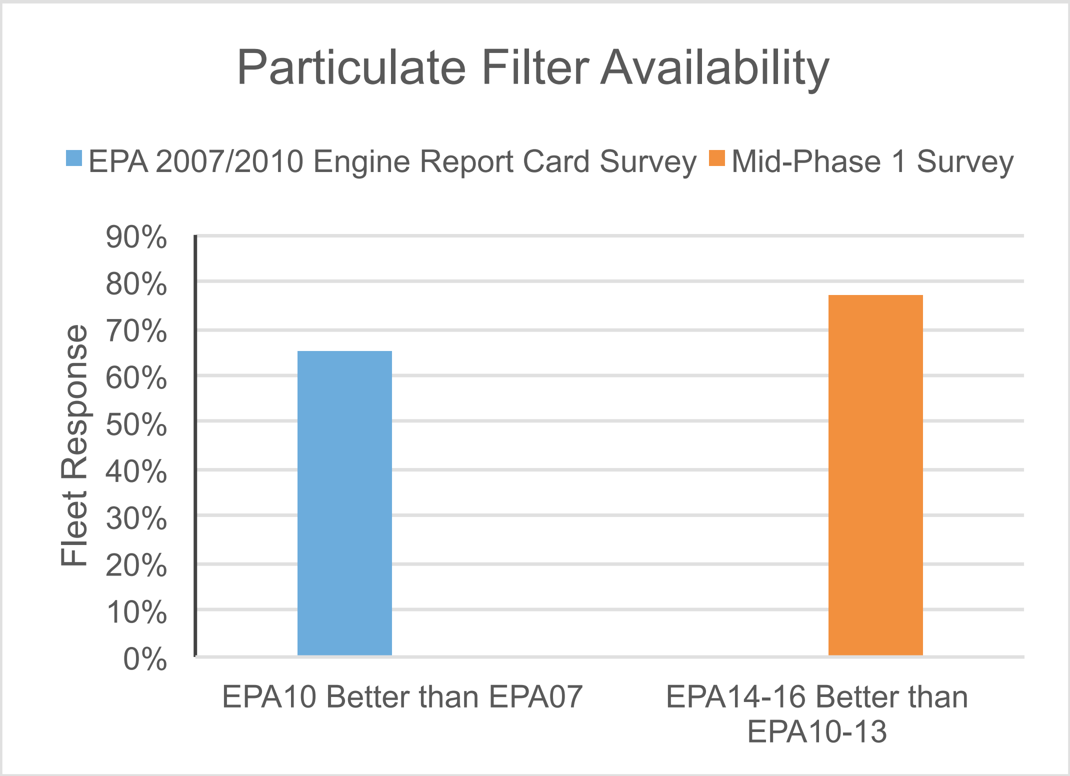


Serviceability, Ease of Diagnostics
Fleet Responses
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Worse than EPA04
Same as EPA04
Better than EPA04
Worse than EPA07
Same as EPA07
Better than EPA07
Worse than EPA10-13
Same as EPA10-13
Better than EPA10-13
EPA07 Engines
EPA10 Engines
EPA14-16 Engines
EPA 2007/2010 Engine Report Card Survey Data
Mid-Phase 1 Survey Data

DATA CHARTS

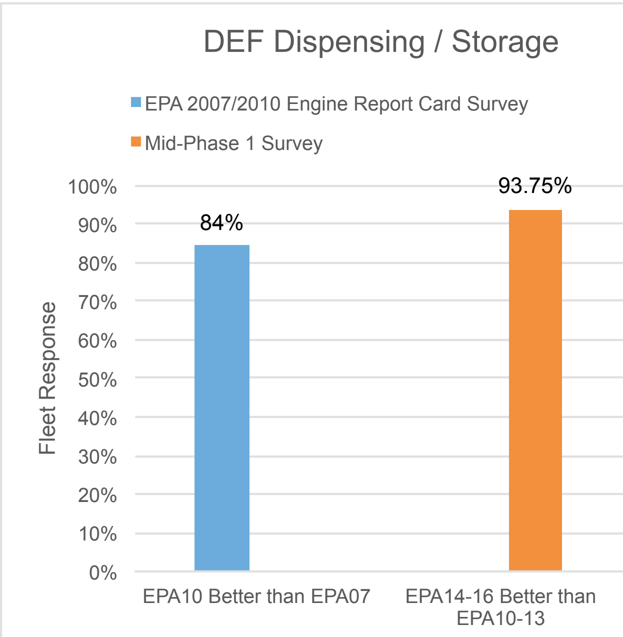


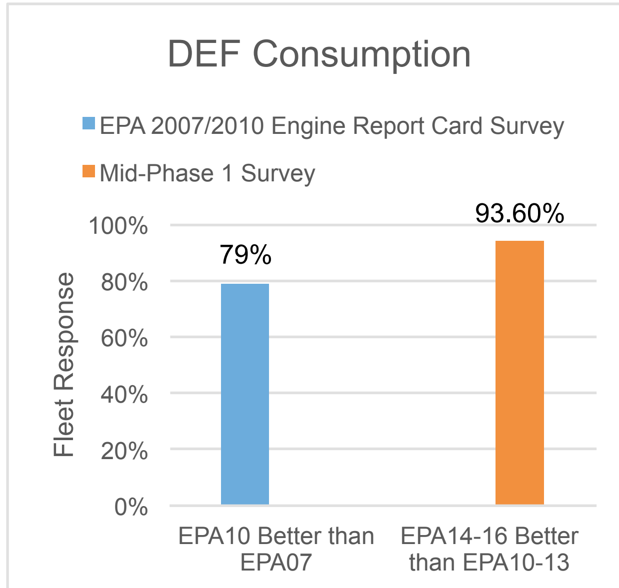
Overall Maintenance Costs
EPA 2007/2010 Engine Report Card Survey Data
TMC's Mid-Phase 1 Survey
Fleet Response
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
79%
14%
50%
36%
36.70%
EPA07 Worse than EPA04
EPA07 Better than EPA04
EPA10 Worse than EPA07
EPA10 Better than EPA07
EPA14-16 Better than EPA10-13

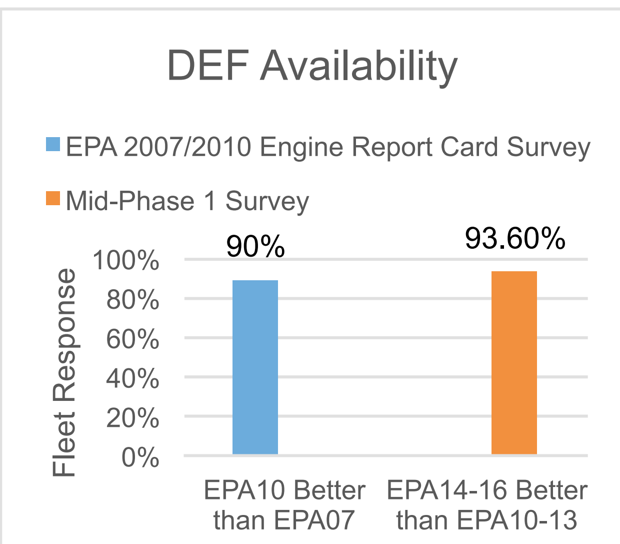


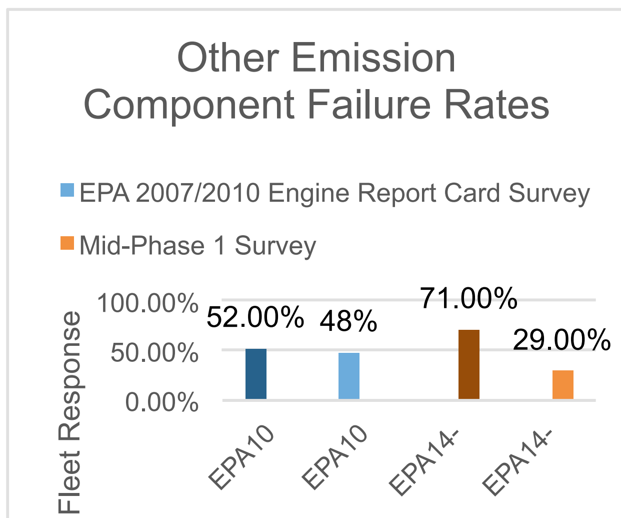
Particulate Filter Availability
EPA 2007/2010 Engine Report Card Survey
Mid-Phase 1 Survey
Fleet Response
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
EPA10 Better than EPA07
EPA14-16 Better than EPA10-13

DATA CHARTS

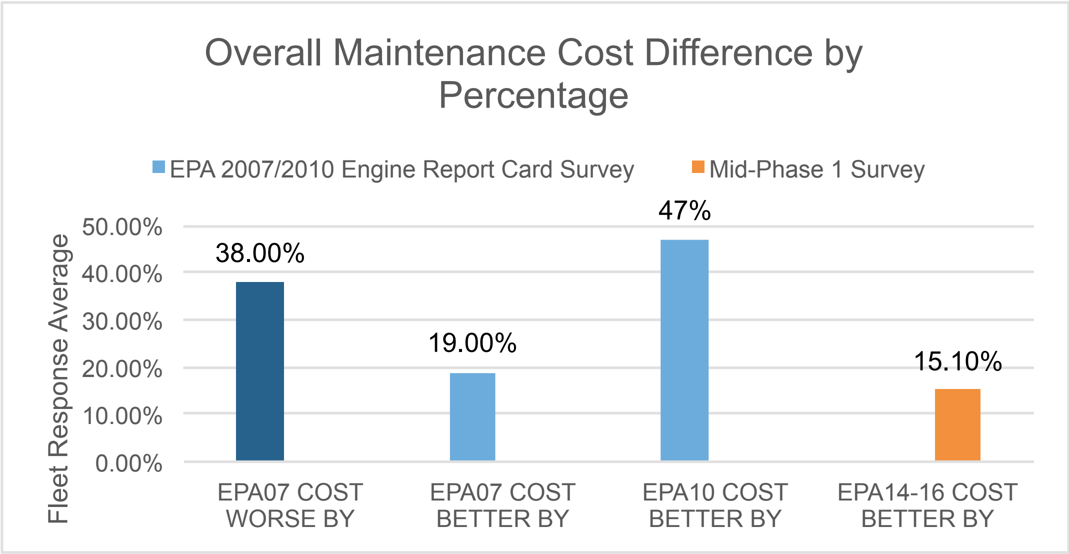

DEF Dispensing / Storage
EPA 2007/2010 Engine Report Card Survey
Mid-Phase 1 Survey
Fleet Response
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
84%
93.75%
EPA10 Better than EPA07
EPA14-16 Better than EPA10-13


DEF Consumption
EPA 2007/2010 Engine Report Card Survey
Mid-Phase 1 Survey
Fleet Response
100%
80%
60%
40%
20%
0%
79%
93.60%
EPA10 Better than EPA07
EPA14-16 Better than EPA10-13

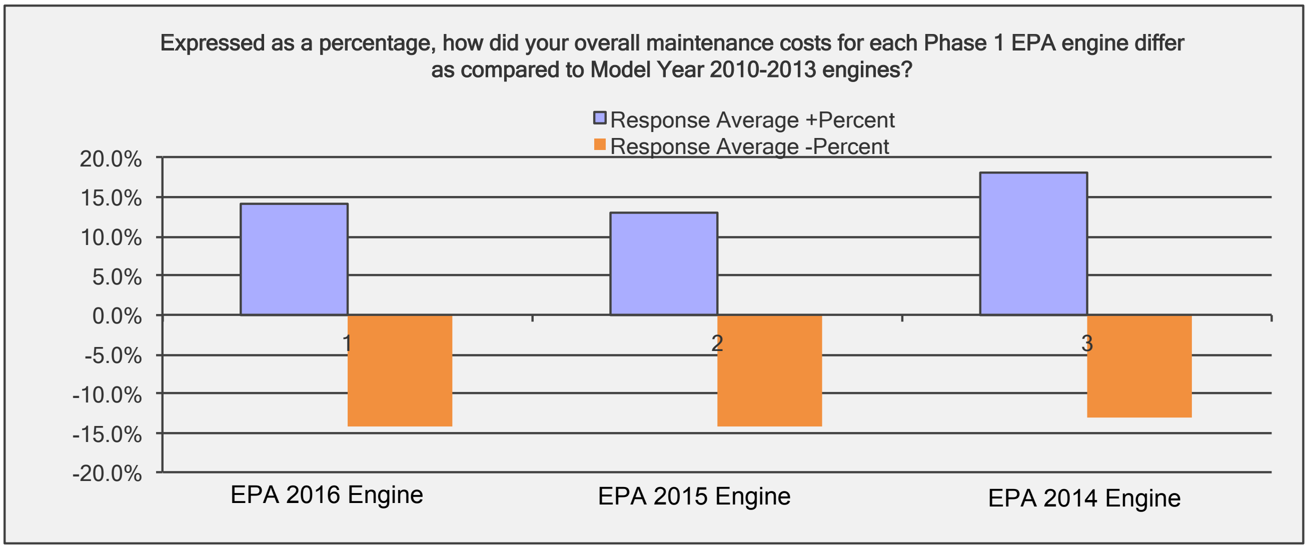

DEF Availability
EPA 2007/2010 Engine Report Card Survey
Mid-Phase 1 Survey
Fleet Response
100%
80%
60%
40%
20%
0%
90%
93.60%
EPA10 Better than EPA07
EPA14-16 Better than EPA10-13


Other Emission Component Failure Rates
EPA 2007/2010 Engine Report Card Survey
Mid-Phase 1 Survey
Fleet Response
100.00%
50.00%
0.00%
52.00%
48%
71.00%
29.00%
EPA10
EPA10
EPA14-
EPA14-

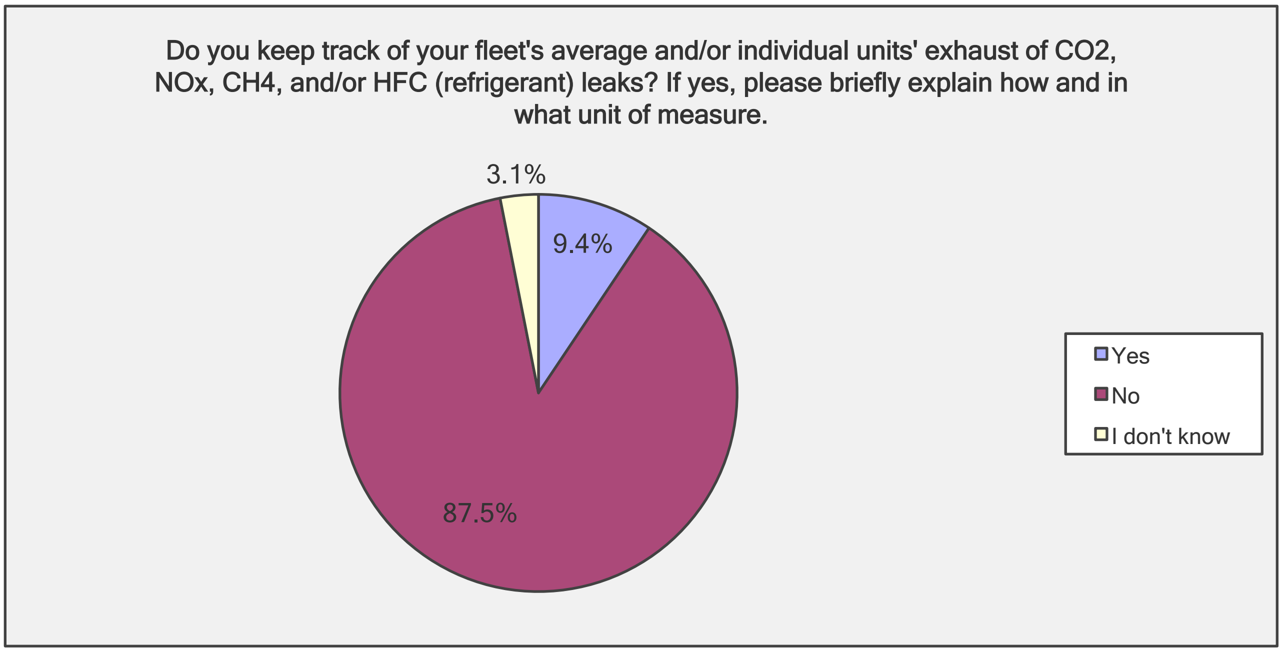
DATA CHARTS

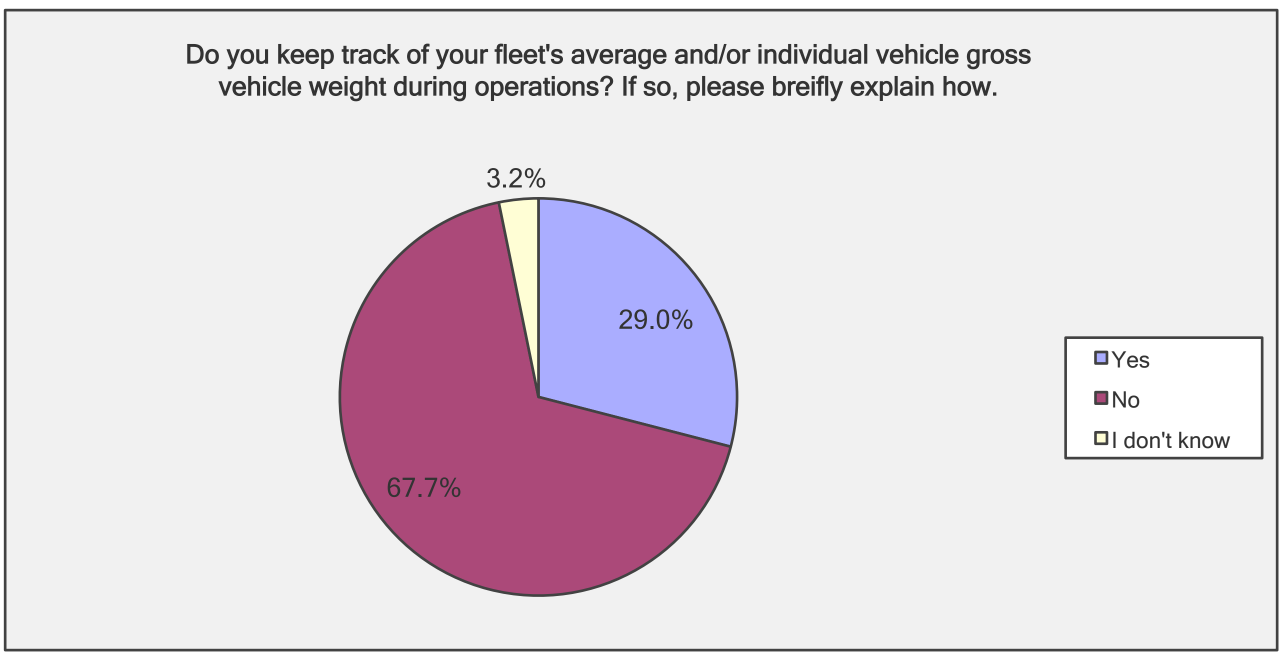


Overall Maintenance Cost Difference by Percentage
EPA 2007/2010 Engine Report Card Survey
Mid-Phase 1 Survey
Fleet Response Average
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
38.00%
19.00%
47%
15.10%
EPA07 COST WORSE BY
EPA07 COST BETTER BY
EPA10 COST BETTER BY
EPA14-16 COST BETTER BY

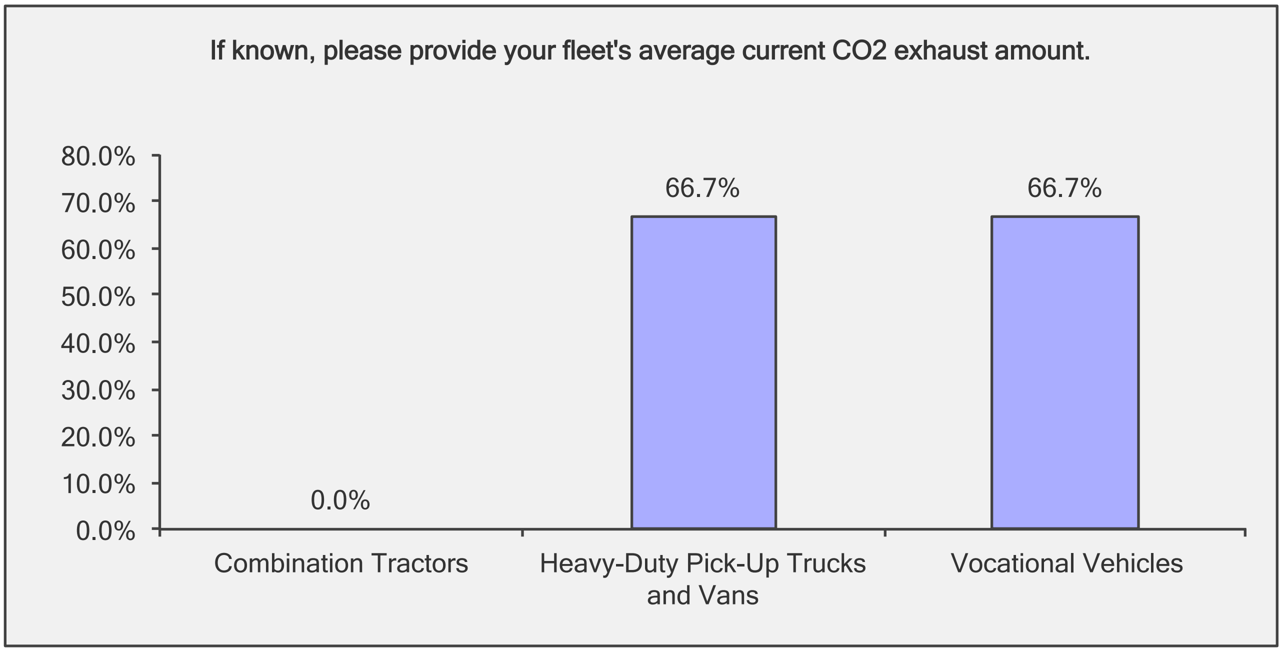


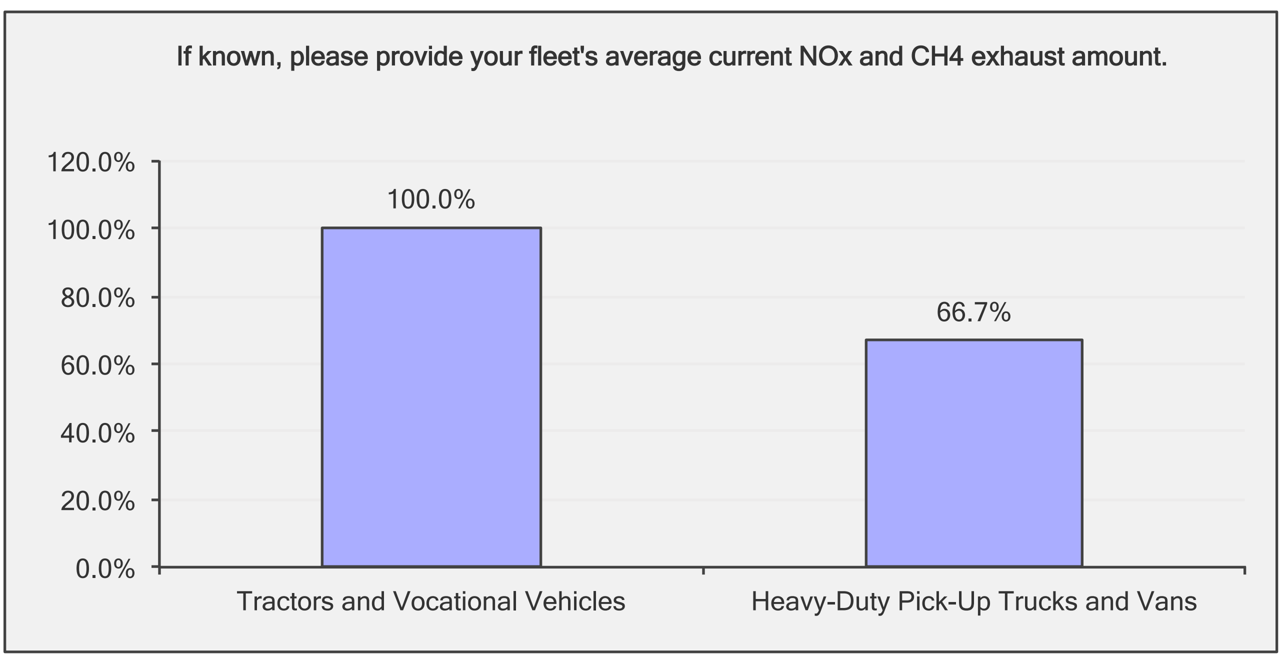
Expressed as a percentage, how did your overall maintenance costs for each Phase 1 EPA engine differ as compared to Model Year 2010-2013 engines?
Response Average +Percent
Response Average -Percent
20.0%
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
-20.0%
1
2
3
EPA 2016 Engine
EPA 2015 Engine
EPA 2014 Engine


Do you keep track of your fleet's average and/or individual units' exhaust of CO2, NOx, CH4, and/or HFC (refrigerant) leaks? If yes, please briefly explain how and in what unit of measure.
3.1%
9.4%
87.5%
Yes
No
I don't know


Do you keep track of your fleet's average and/or individual vehicle gross vehicle weight during operations? If so, please breifly explain how.
3.2%
29.0%
67.7%
Yes
No
I don't know

DATA CHARTS


If known, please provide your fleet's average current CO2 exhaust amount.
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0.0%
66.7%
66.7%
Combination Tractors
Heavy-Duty Pick-Up Trucks and Vans
Vocational Vehicles


If known, please provide your fleet's average current NOx and CH4 exhaust amount.
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
100.0%
66.7%
Tractors and Vocational Vehicles
Heavy-Duty Pick-Up Trucks and Vans

APPENDIX

Reported Performance of Mid-Phase 1 2014-2016 EPA/NHTSA Generation Trucks

OFFICIAL SURVEY

Technology & Maintenance Council

TMC
Turning Experience Into Practice

Reported Performance of Mid-Phase 1 2014-2016 EPA/NHTSA Generation Trucks

Developed by the Technology & Maintenance Council's (TMC)
S.3 Engine Study Group

ABSTRACT

Thirty-six individuals responded to TMC's "EPA/NHTSA GHG & Fuel Efficiency National Program Mid-Phase 1 Scorecard Survey," which was administered in August-October 2016. Respondents submitted data on EPA/NHTSA Phase 1 engine performance and fleet experience as compared to EPA Model Year 2010-2013 engines, covering more than 30 categories. The survey respondents' companies represented 48,763 power units of the U.S. trucking industry. Of the Class 7 and 8 power units, about 67 percent of responding fleets were equipped with EPA 2014, 2015, and 2016 engines; while 24 percent were equipped with EPA 2010-2013 engines.

Of those responding, 77 percent rated the fuel economy performance of EPA 2014-2016 engines as "Better than" EPA 2010-2013 engines. Over 62 percent rated EGR-related component failure rates of EPA 2014-2016 engines as "Better than" EPA 2010-2013 engines. For the following two categories — Drivers' Understanding of Aftertreatment Systems, and Drivers' Understanding of Engine Malfunction Indicators – 73 percent rated EPA 2014-2016 engines "Same as" EPA 2010-2013 engines. Also, 71 percent of respondents rated emissions component failure rates as "Below Expectations" since the beginning of Phase 1.

March 1, 2017

COUNCIL OF ATA

Technology & Maintenance Council (TMC)
950 N. Glebe Road • Arlington, VA 22203 • Ph: (703) 838-1776 • FAX: (703) 838-1701
tmc@trucking.org • http://tmc.trucking.org

INTRODUCTION

In August 2011, the U.S. Environmental Protection Agency (EPA) and Department of Transportation's National Highway Traffic Safety Administration (NHTSA) announced a first-ever "Phase 1" regulation program to reduce greenhouse gas (GHG) emissions and improve fuel efficiency for model year 2014-2018 heavy-duty trucks and buses.

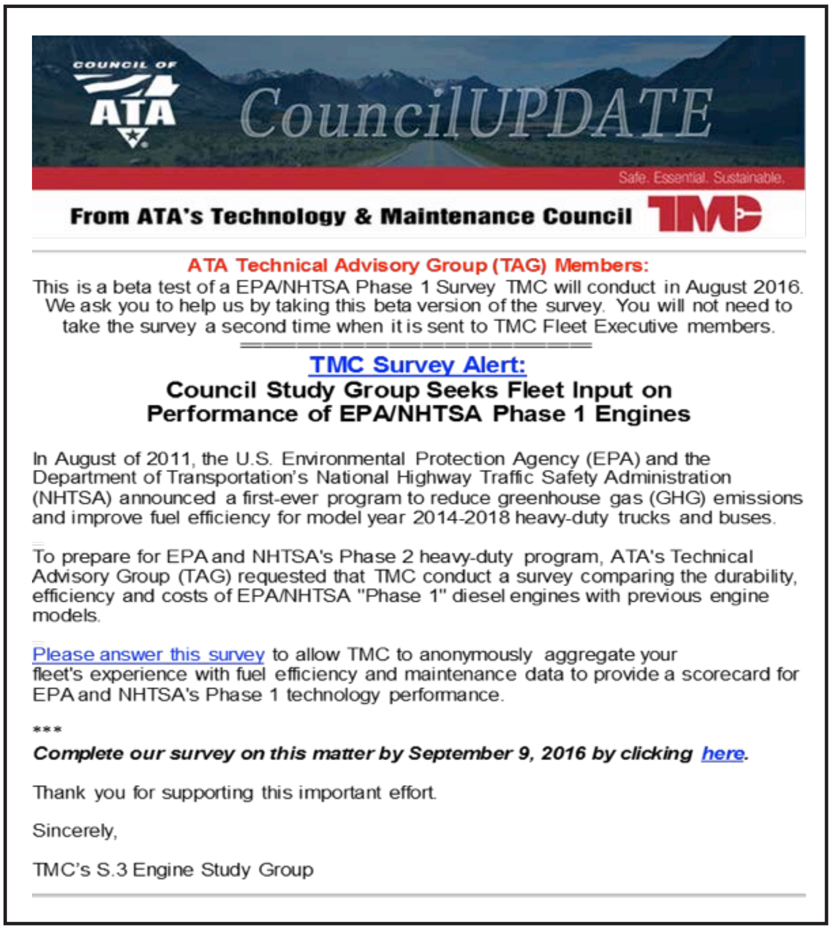
To prepare for EPA and NHTSA's Phase 2 program, the American Trucking Associations' (ATA) Technical Advisory Group (TAG) requested ATA's Technology & Maintenance Council (TMC) to conduct a survey comparing the durability, efficiency and costs of EPA/NHTSA "Phase 1" diesel engines with previous engine models.

The purpose of the survey was to:

- assist fleet maintenance executives in their decisions on fleet maintenance costs and expectations in preparing for Phase 2; and;
- determine how the GHG program was progressing for fleets in reducing emissions standards for carbon dioxide (CO_2), oxides of nitrogen (NO_x), and methane (CH_4) as well as control over hydrofluorocarbon (HFC) leaks from air conditioning systems.

METHODOLOGY

Survey alerts were sent via email to more than 500 TMC fleet executive members and more than 1200 ATA motor carrier members on August 1, 2016, with reminder notices being sent on September 19th and October 10th. **Figure 1** illustrates how the survey notice email appeared to recipients.



ATA Technical Advisory Group (TAG) Members:
This is a beta test of a EPA/NHTSA Phase 1 Survey TMC will conduct in August 2016. We ask you to help us by taking this beta version of the survey. You will not need to take the survey a second time when it is sent to TMC Fleet Executive members.

TMC Survey Alert:
Council Study Group Seeks Fleet Input on Performance of EPA/NHTSA Phase 1 Engines

In August of 2011, the U.S. Environmental Protection Agency (EPA) and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) announced a first-ever program to reduce greenhouse gas (GHG) emissions and improve fuel efficiency for model year 2014-2018 heavy-duty trucks and buses.

To prepare for EPA and NHTSA's Phase 2 heavy-duty program, ATA's Technical Advisory Group (TAG) requested that TMC conduct a survey comparing the durability, efficiency and costs of EPA/NHTSA "Phase 1" diesel engines with previous engine models.

Please answer this survey to allow TMC to anonymously aggregate your fleet's experience with fuel efficiency and maintenance data to provide a scorecard for EPA and NHTSA's Phase 1 technology performance.

***

Complete our survey on this matter by September 9, 2016 by clicking here.

Thank you for supporting this important effort.

Sincerely,

TMC's S.3 Engine Study Group

Figure 1

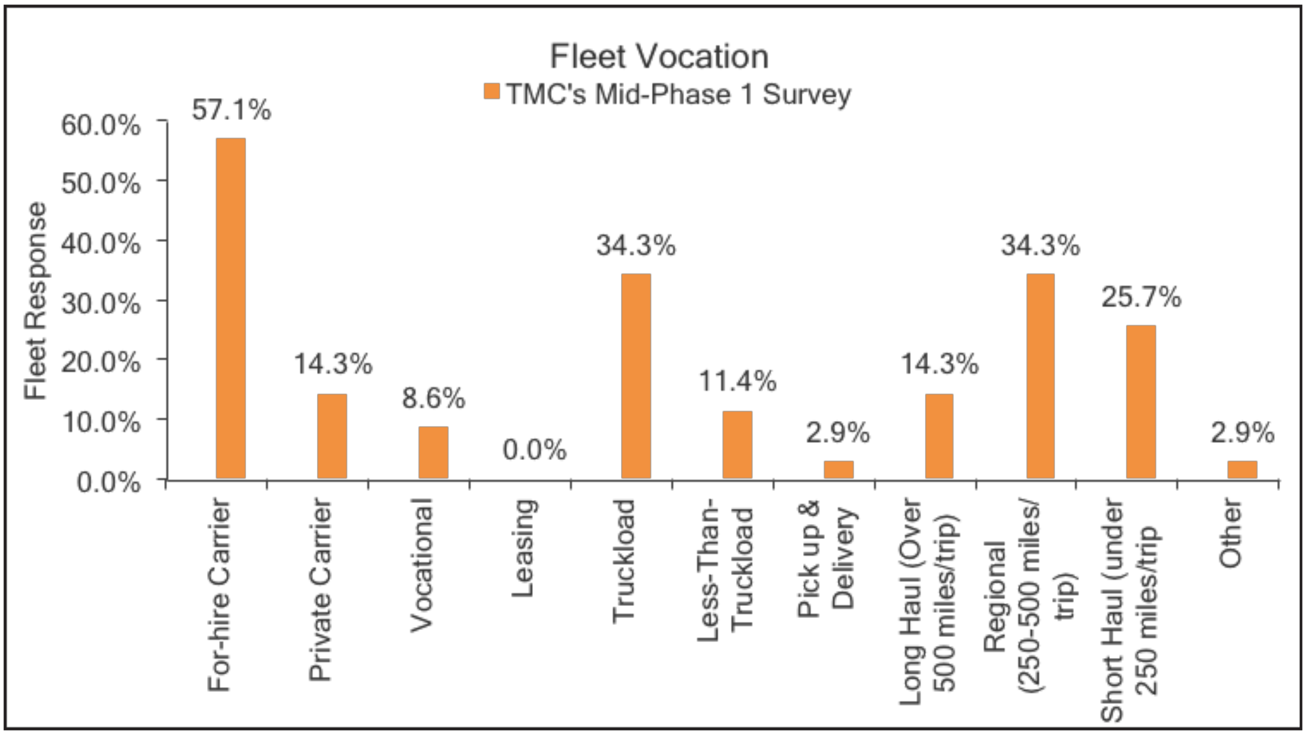
The survey was conducted using SurveyMonkey. Eblast alerts were generated using Bluehornet's High Roads email management system. Thirty-six fleets attempted to complete at least a portion of the survey. The survey was activated on August 1, 2016. The survey was closed November 1, 2016.

RESULTS

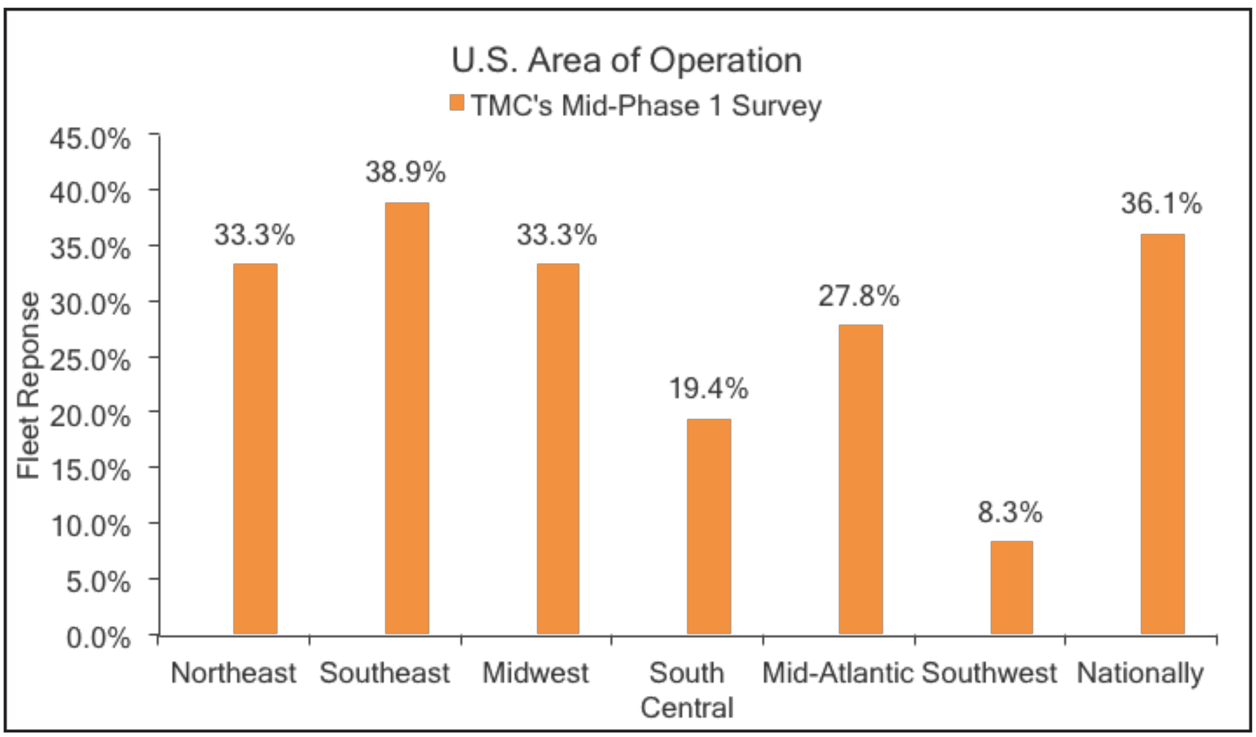
The federal agencies estimated that the combined standards under Phase 1 would reduce CO_2 emissions by about 270 million metric tons and save about 530 million barrels of oil over the life of vehicles built in 2014-2018 model years, providing $49 billion in net program benefits. The reduced fuel use alone will enable $50 billion in fuel savings to accrue to vehicle owners, or $42 billion in net savings when considering technology costs.

The following questions were answered to allow TMC to anonymously aggregate fleet experiences with fuel efficiency and maintenance data to provide a scorecard for EPA and NHTSA's Phase 1:

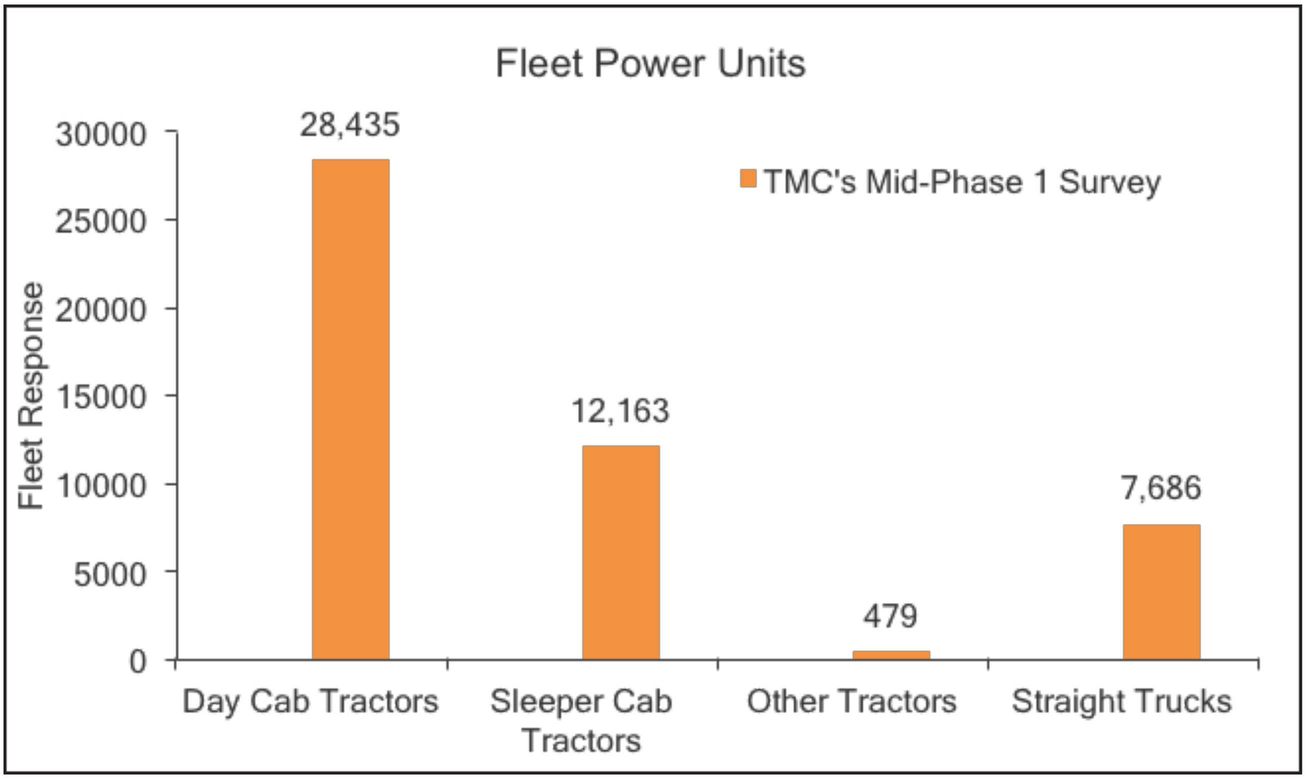
Q1. Which of the following best describes your company's operation?



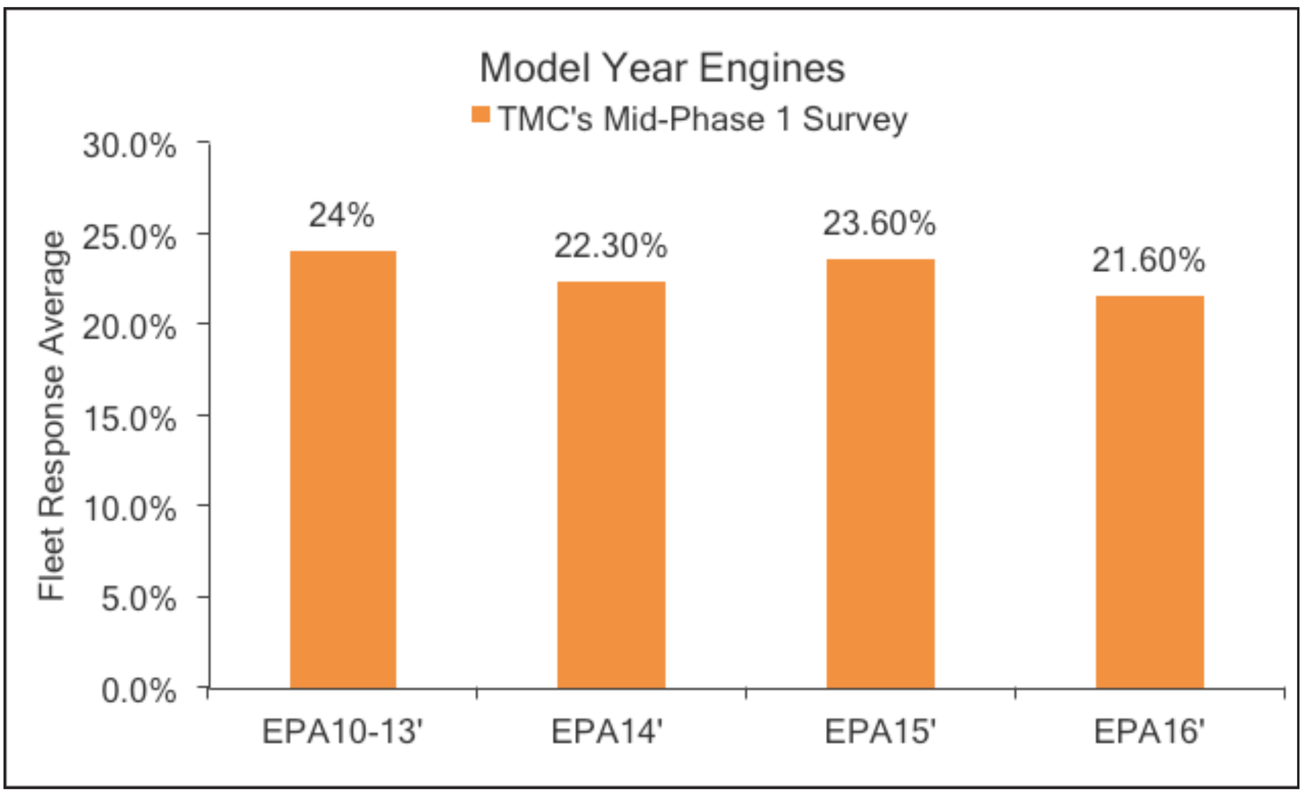
Q2. What area of the continental U.S. does your fleet operate?



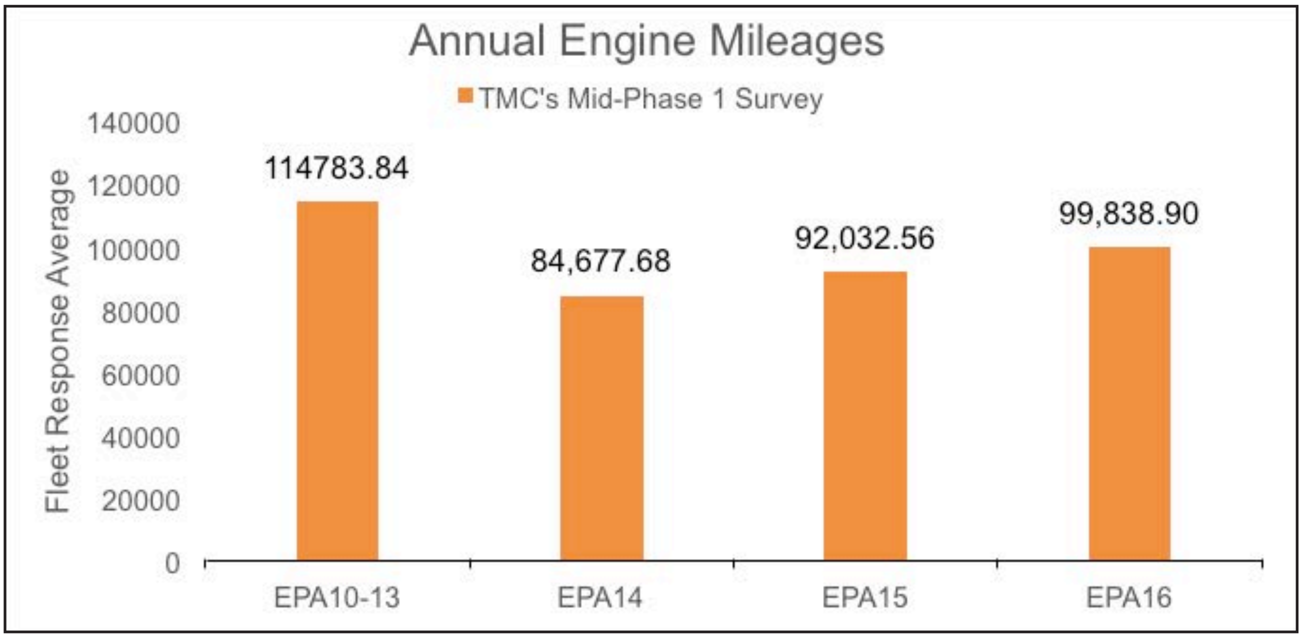
Q3. How many of the following pieces of equipment does your fleet operate?



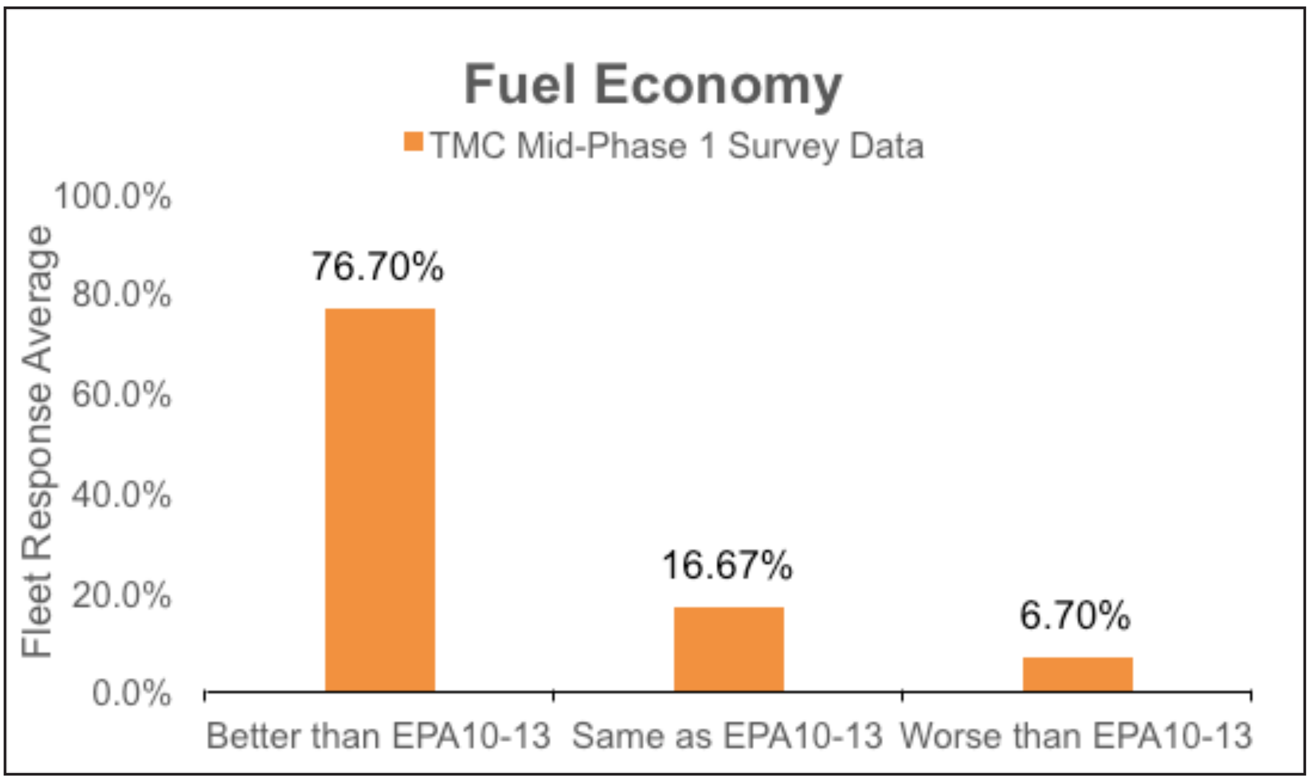
Q4. What percentage of your fleet's Class 7 & 8 tractors are powered by:

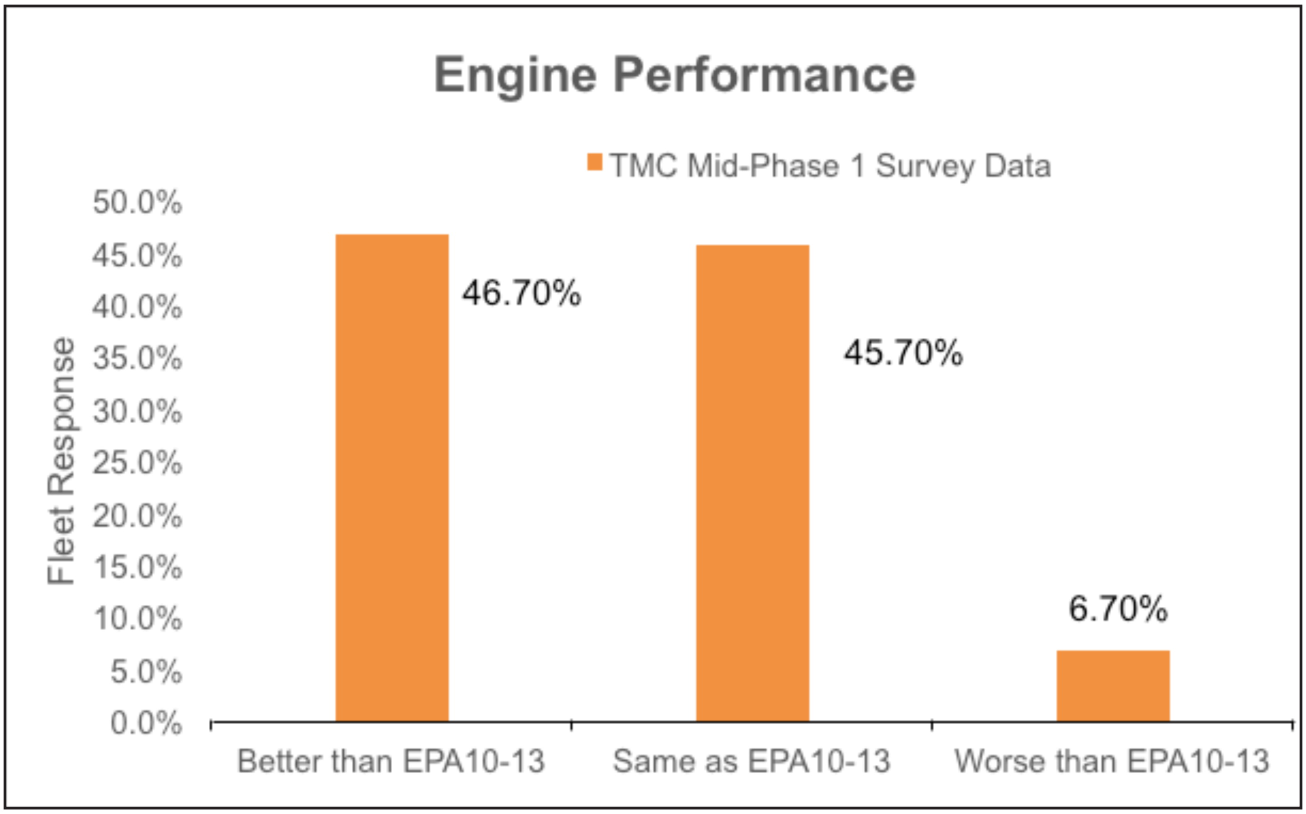


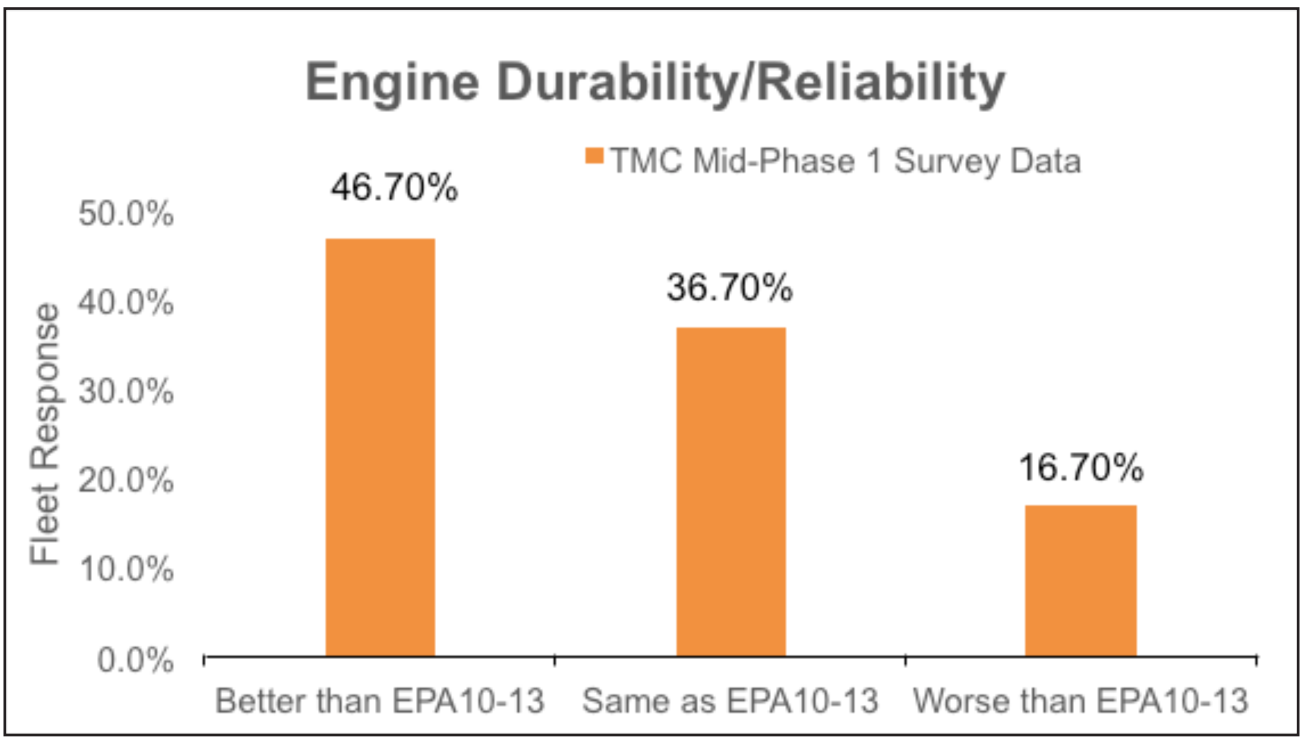
Q5. What are your fleet's average annual mileages of each tractor configured with the following engines?

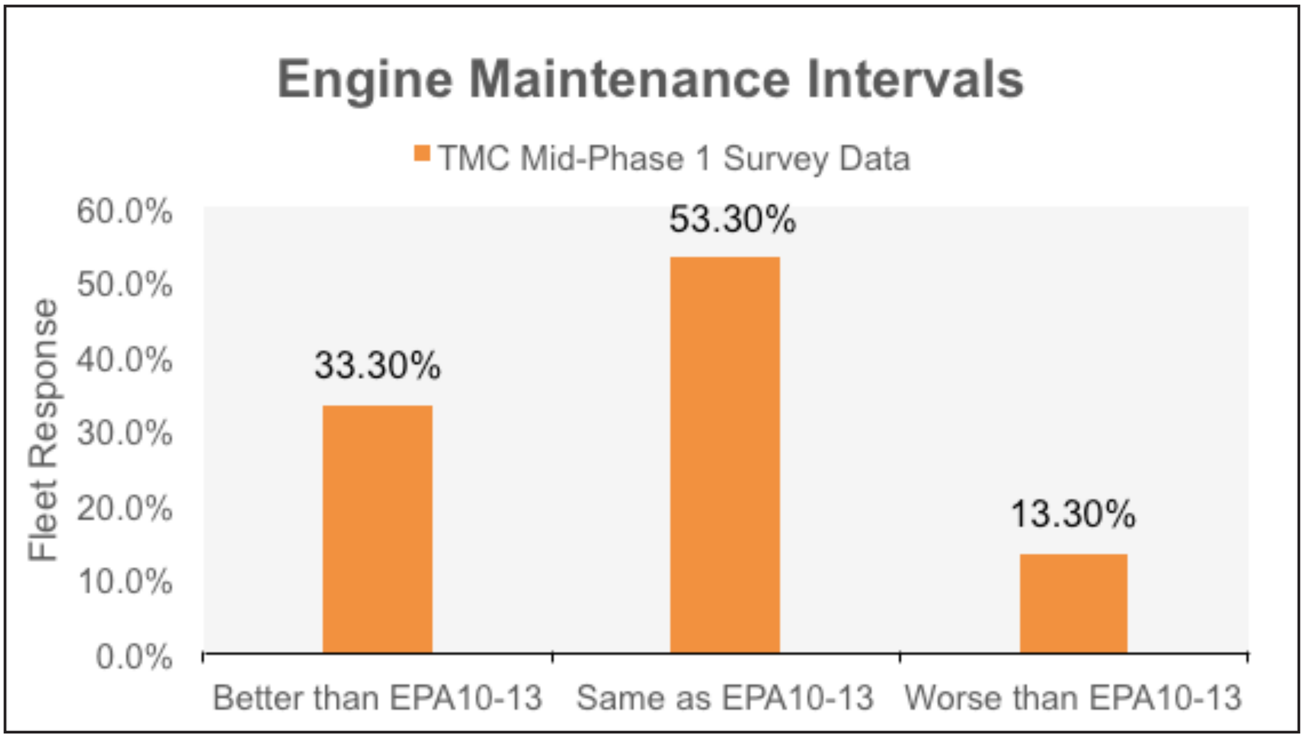


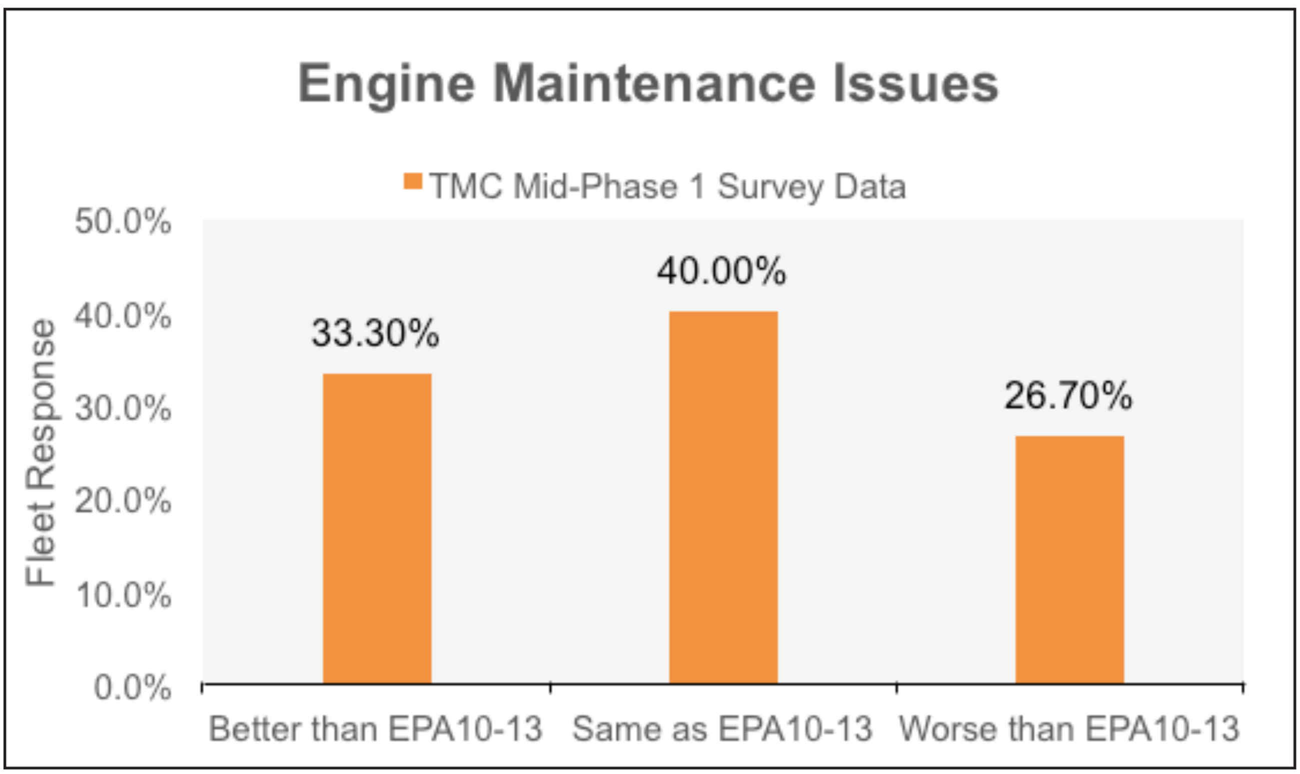
Q6. Based on your fleet's experience, how do you rate EPA/NHTSA's Phase 1 engine performance (i.e., EPA 2014-2016 engines) as compared to EPA Model Year 2010-2013 engines in each of the following categories?

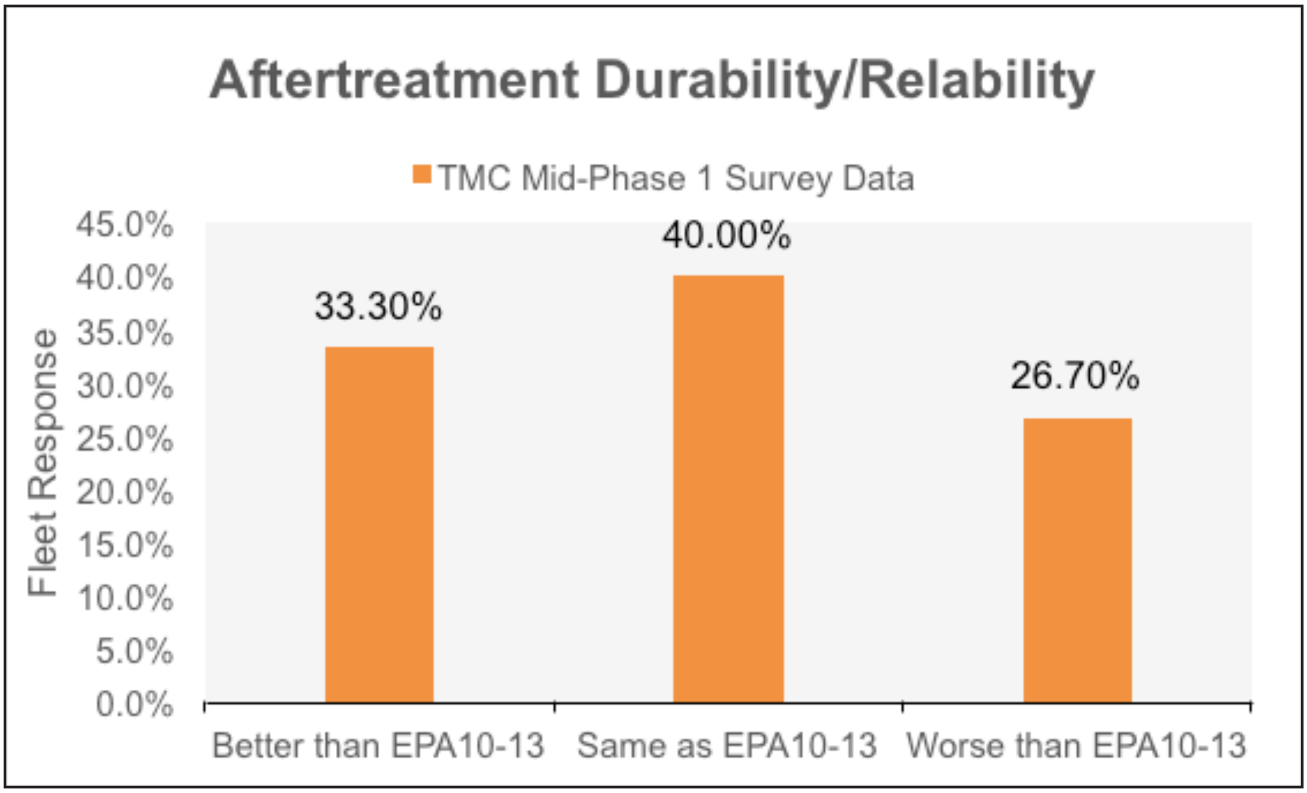


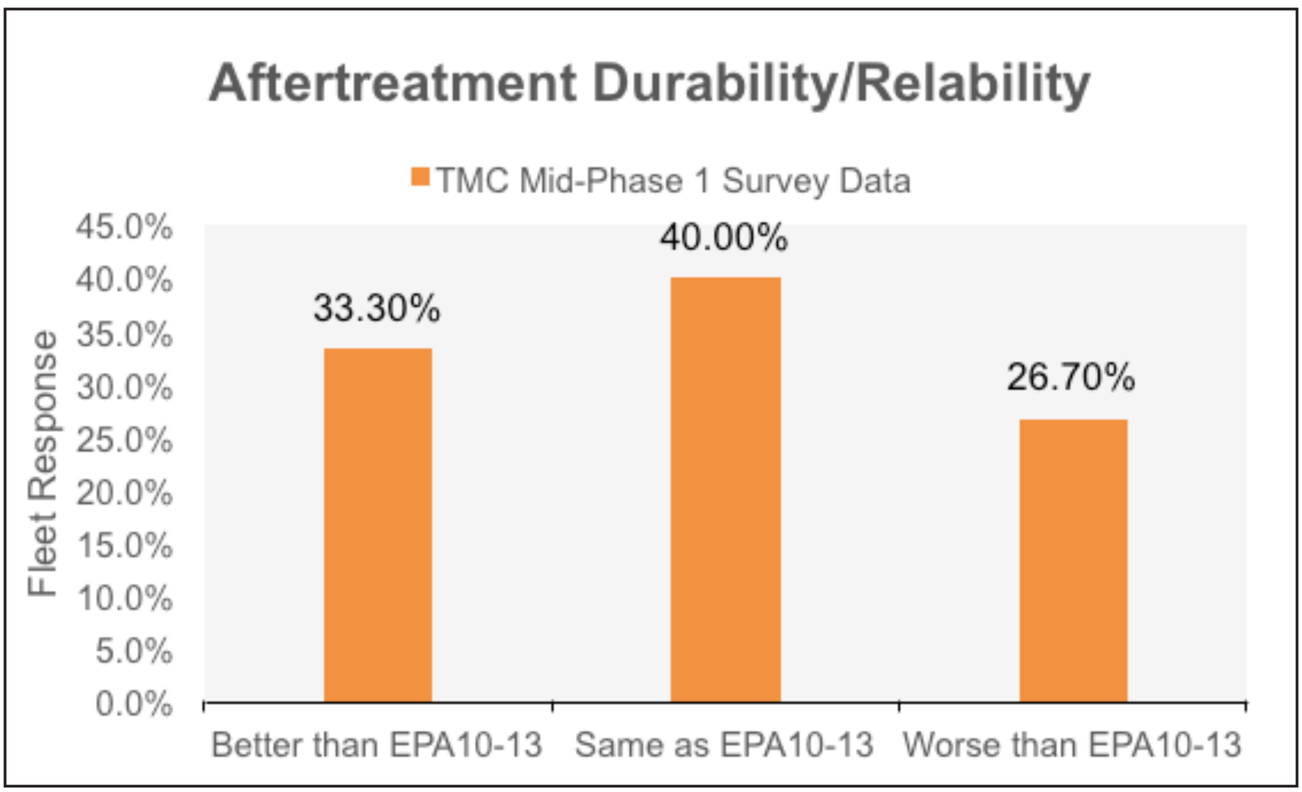

Engine Performance
TMC Mid-Phase 1 Survey Data
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Fleet Response
46.70%
45.70%
6.70%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

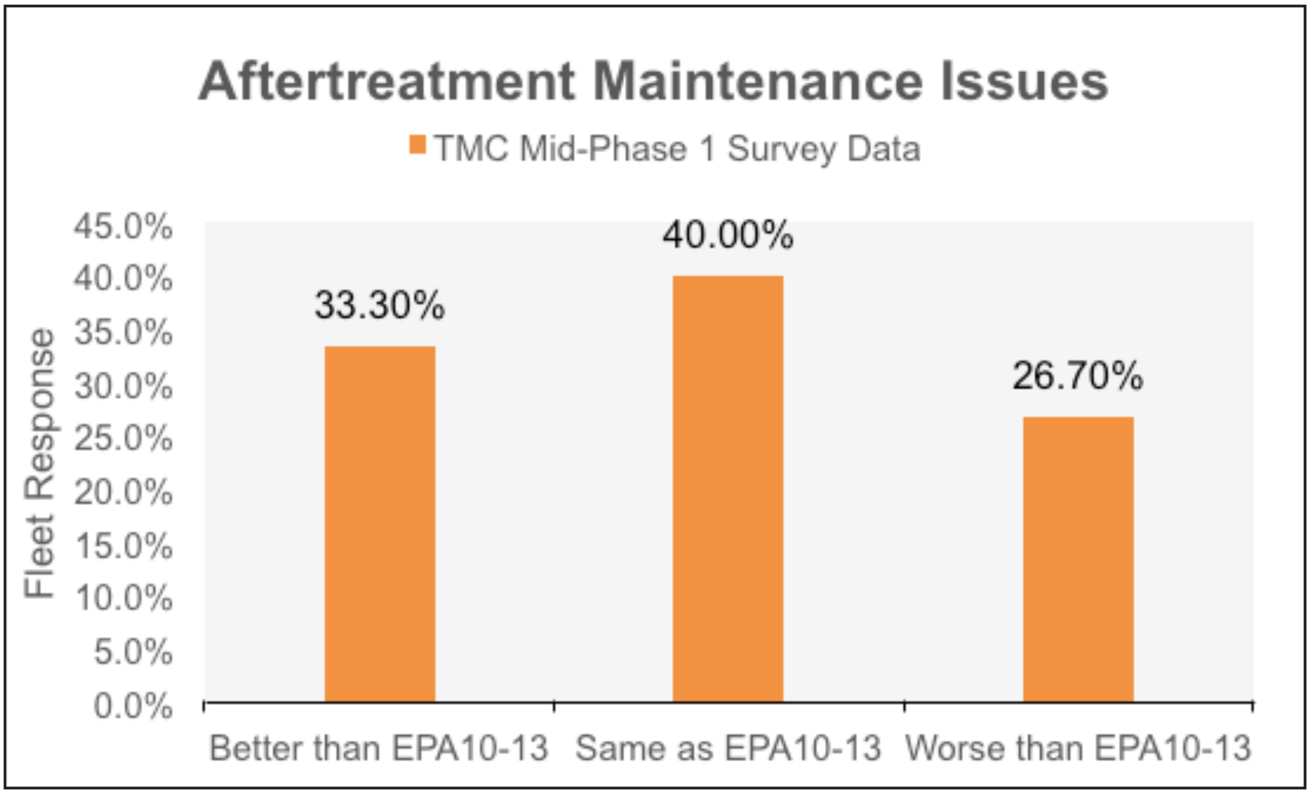

Engine Durability/Reliability
TMC Mid-Phase 1 Survey Data
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Fleet Response
46.70%
36.70%
16.70%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

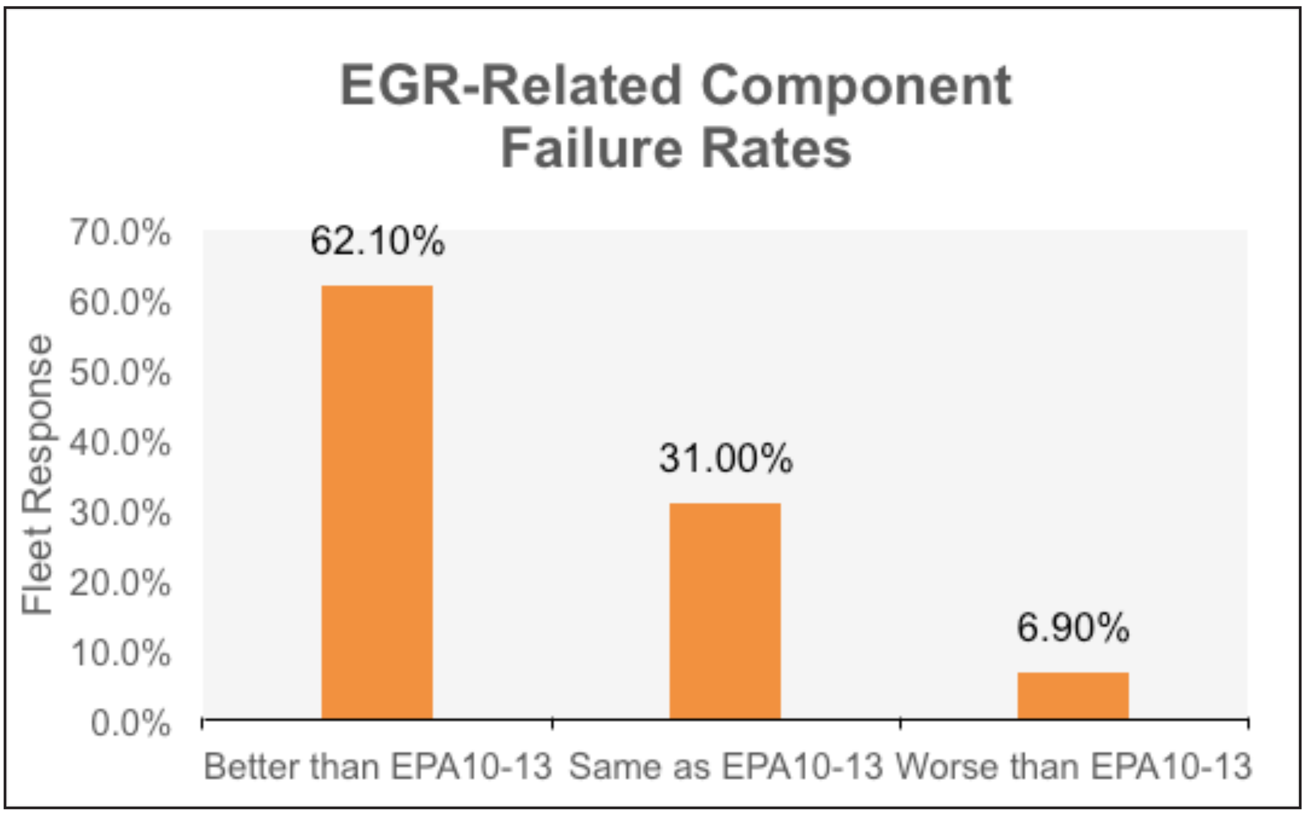

Engine Maintenance Intervals
TMC Mid-Phase 1 Survey Data
Fleet Response
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
33.30%
53.30%
13.30%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

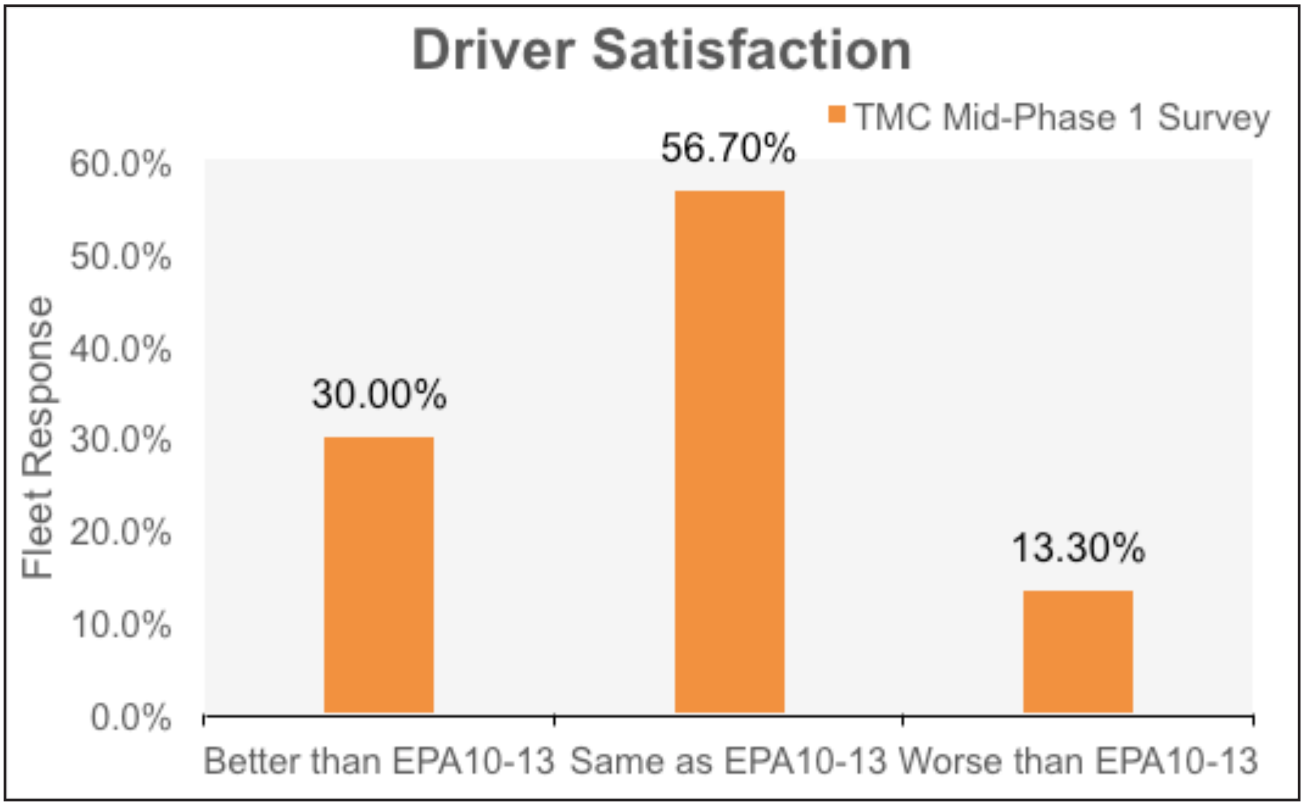

Engine Maintenance Issues
TMC Mid-Phase 1 Survey Data
Fleet Response
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
33.30%
40.00%
26.70%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13


Aftertreatment Durability/Relability
TMC Mid-Phase 1 Survey Data
Fleet Response
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
33.30%
40.00%
26.70%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

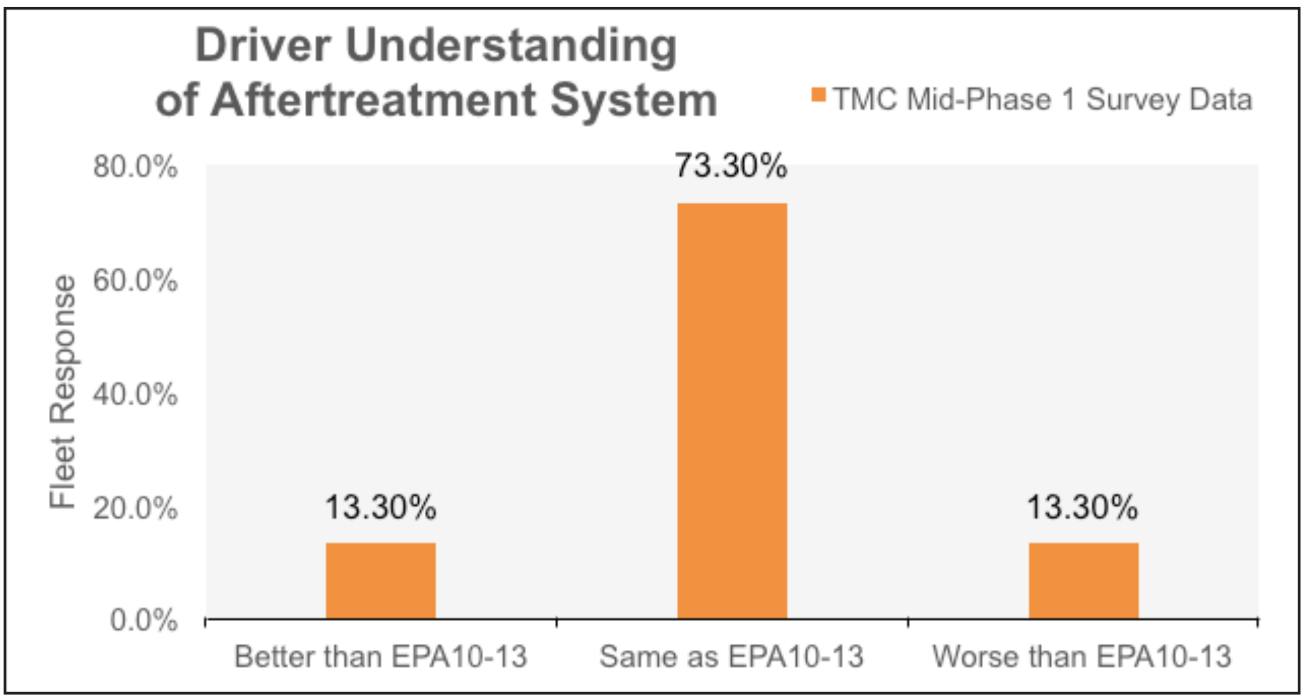

Aftertreatment Durability/Relability
TMC Mid-Phase 1 Survey Data
Fleet Response
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
33.30%
40.00%
26.70%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13


Aftertreatment Maintenance Issues
TMC Mid-Phase 1 Survey Data
Fleet Response
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
33.30%
40.00%
26.70%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

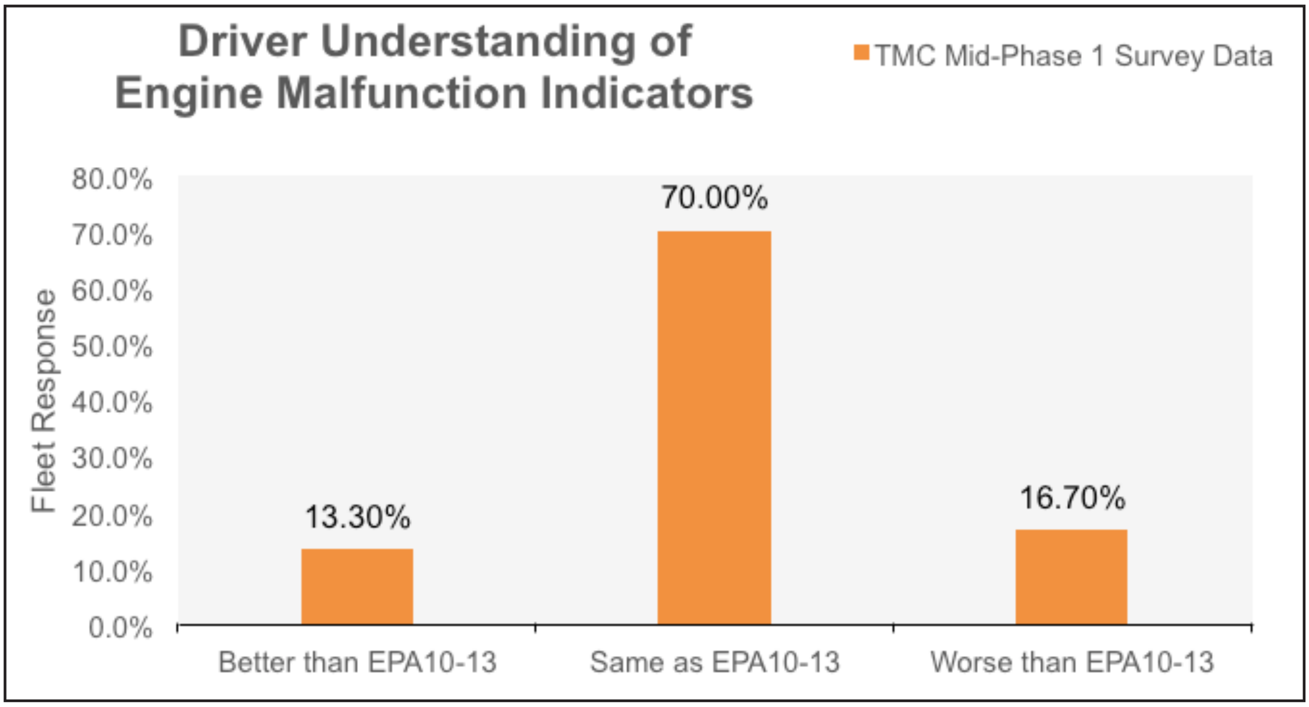

EGR-Related Component Failure Rates
Fleet Response
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
62.10%
31.00%
6.90%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

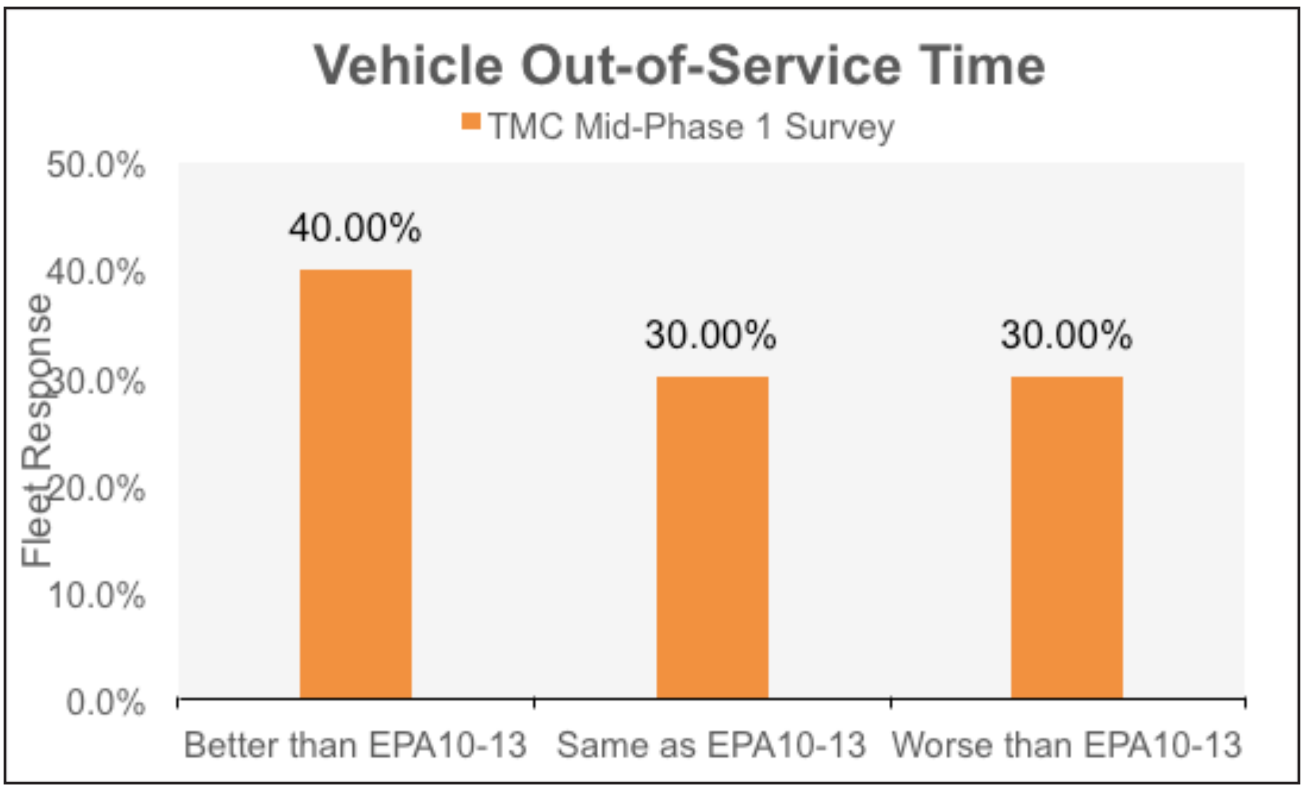


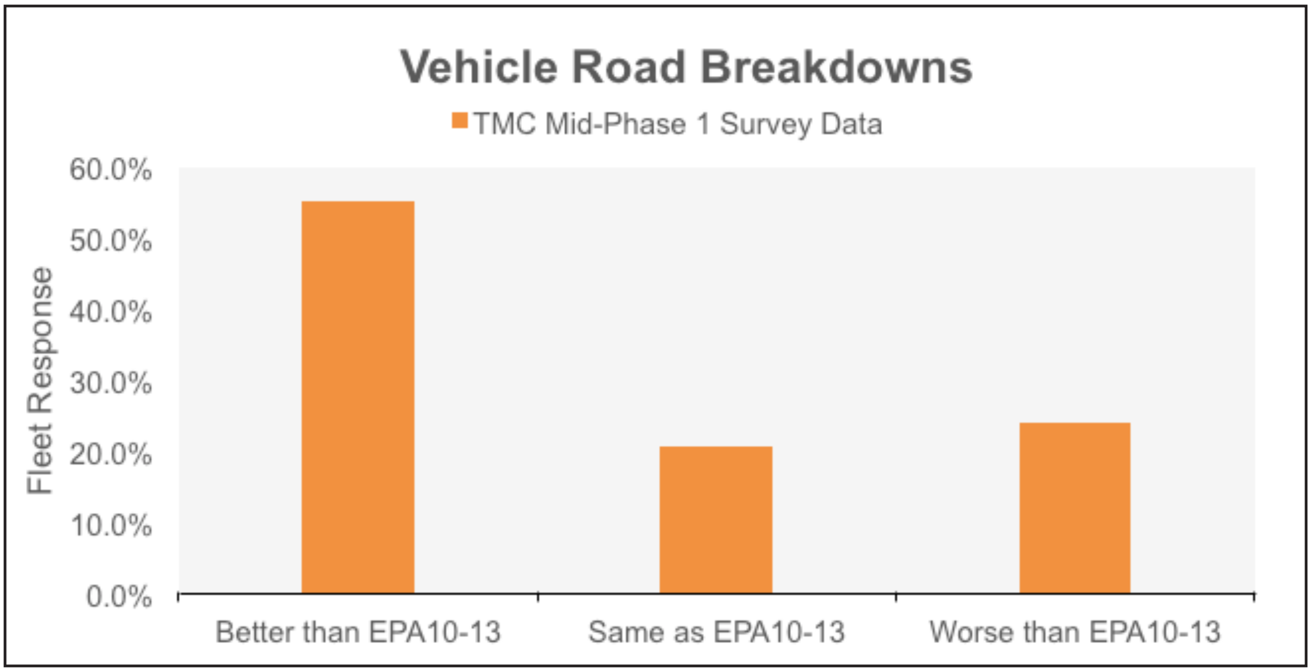
Driver Satisfaction
TMC Mid-Phase 1 Survey
Fleet Response
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
30.00%
56.70%
13.30%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

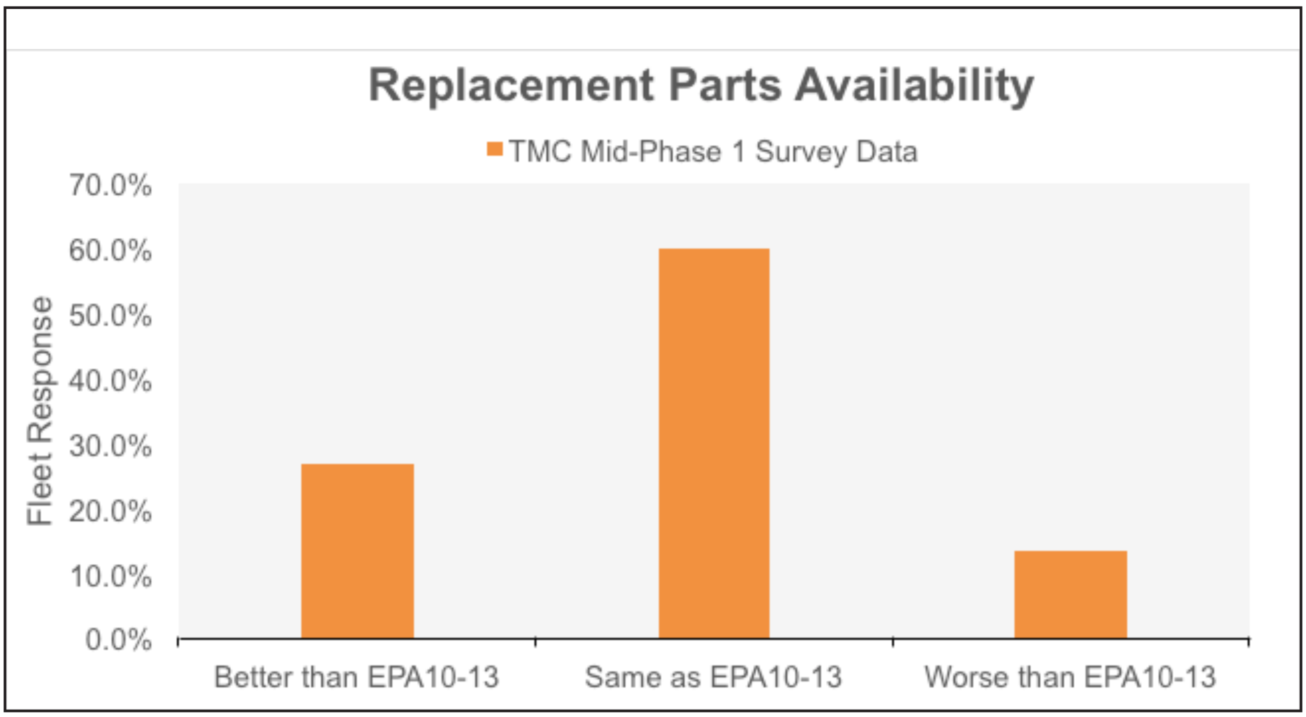


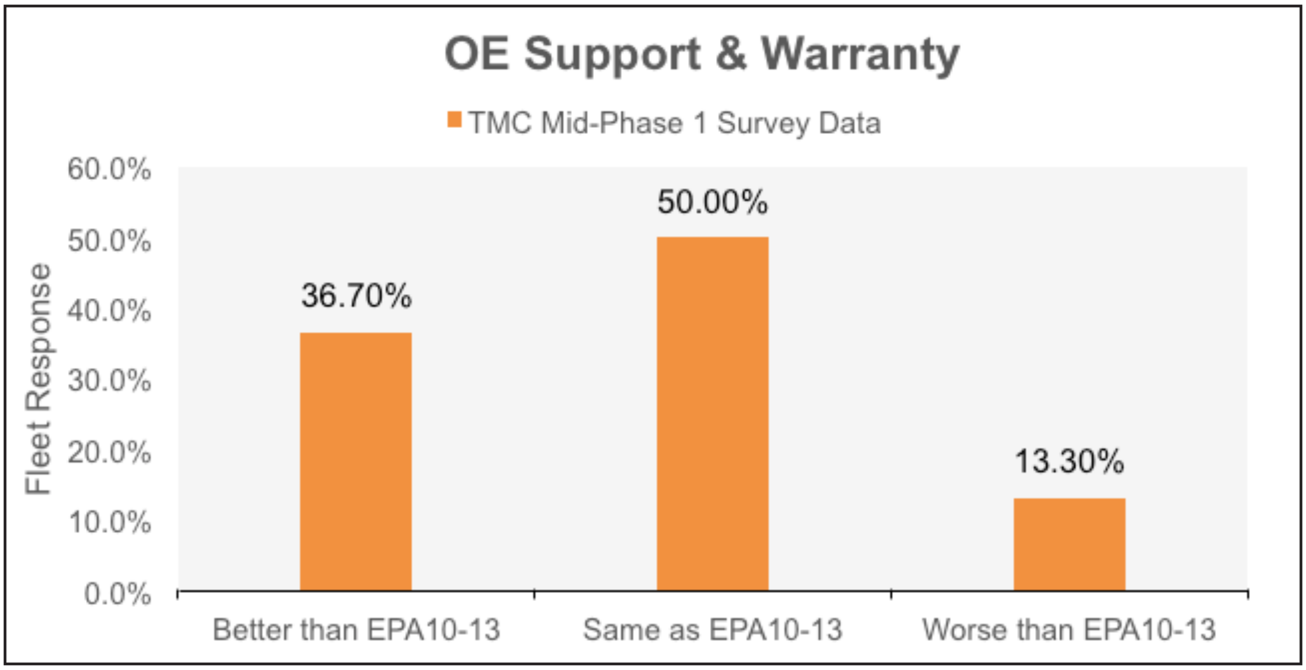
Driver Understanding of Aftertreatment System
TMC Mid-Phase 1 Survey Data
Fleet Response
80.0%
60.0%
40.0%
20.0%
0.0%
13.30%
73.30%
13.30%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13


Driver Understanding of
Engine Malfunction Indicators
TMC Mid-Phase 1 Survey Data
Fleet Response
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
13.30%
70.00%
16.70%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

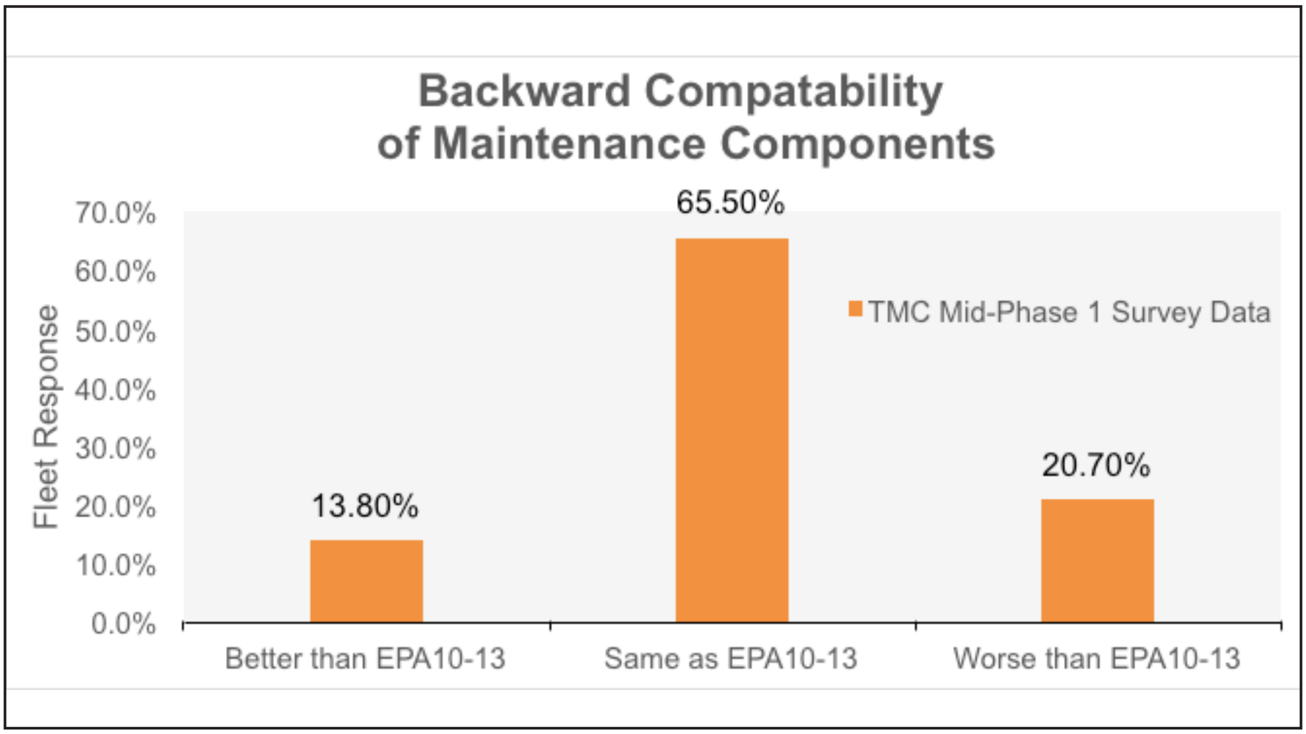

Vehicle Out-of-Service Time
TMC Mid-Phase 1 Survey
Fleet Response
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
40.00%
30.00%
30.00%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13


Vehicle Road Breakdowns
TMC Mid-Phase 1 Survey Data
Fleet Response
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

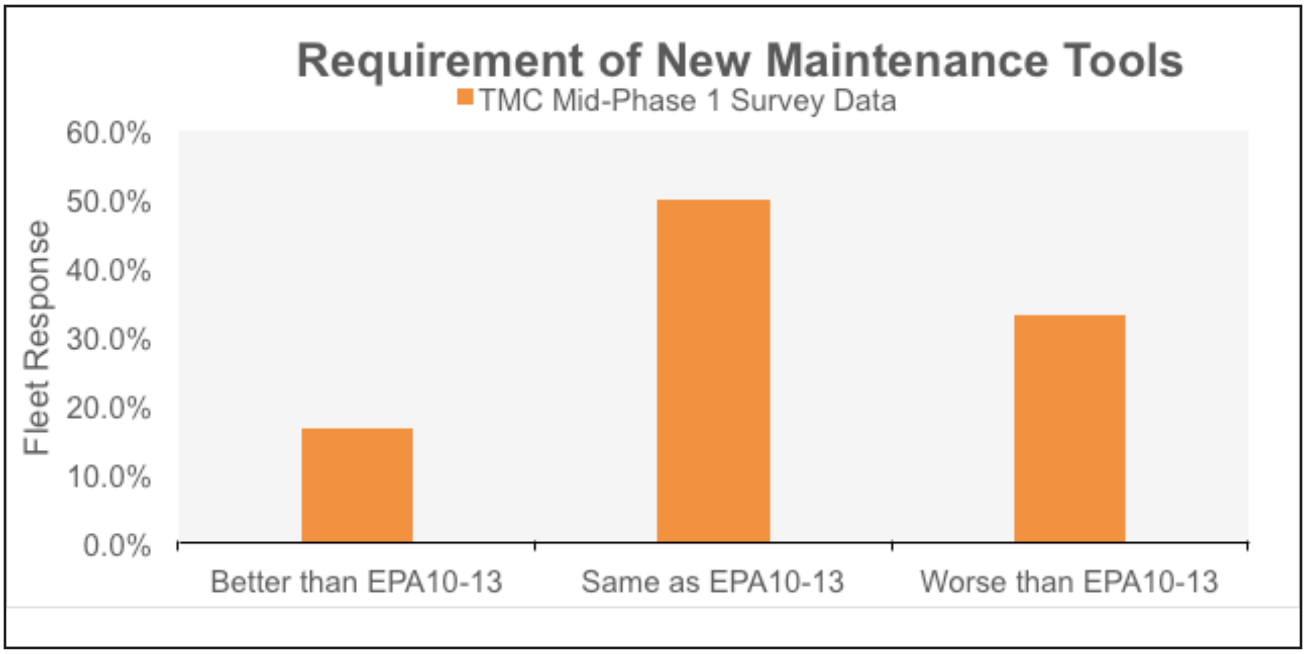

Replacement Parts Availability
TMC Mid-Phase 1 Survey Data
Fleet Response
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

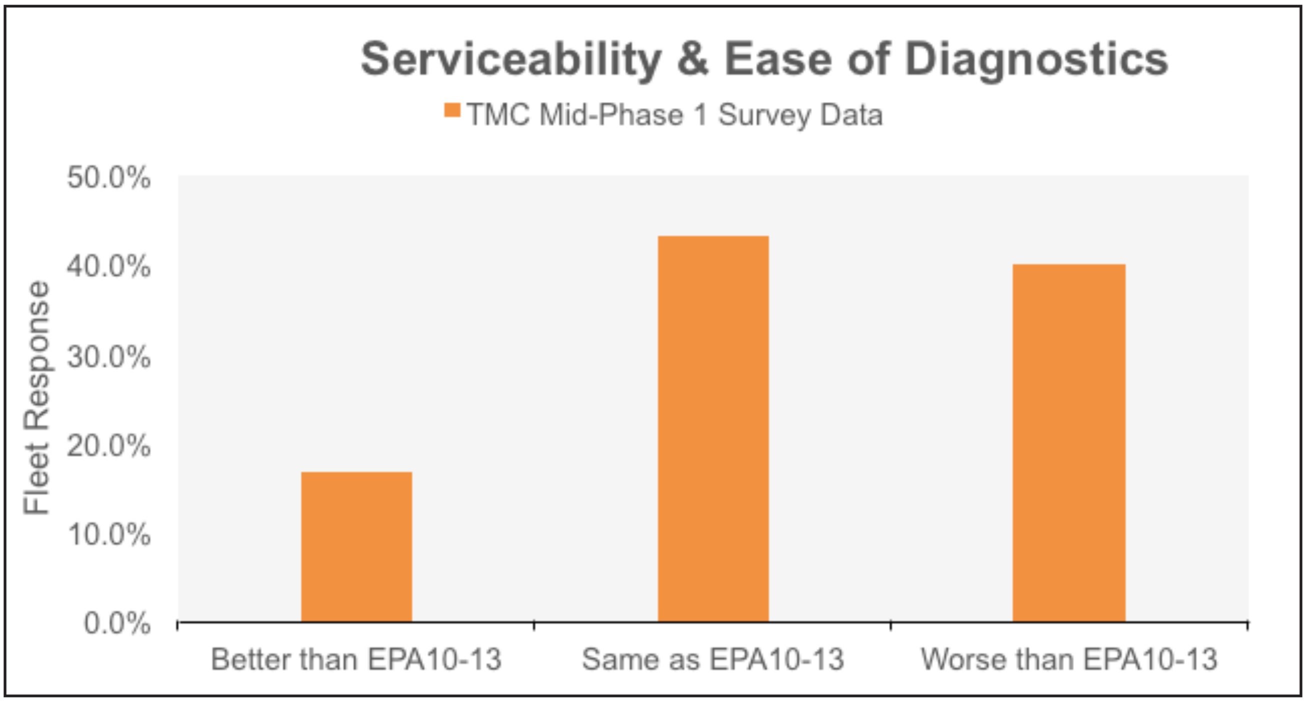


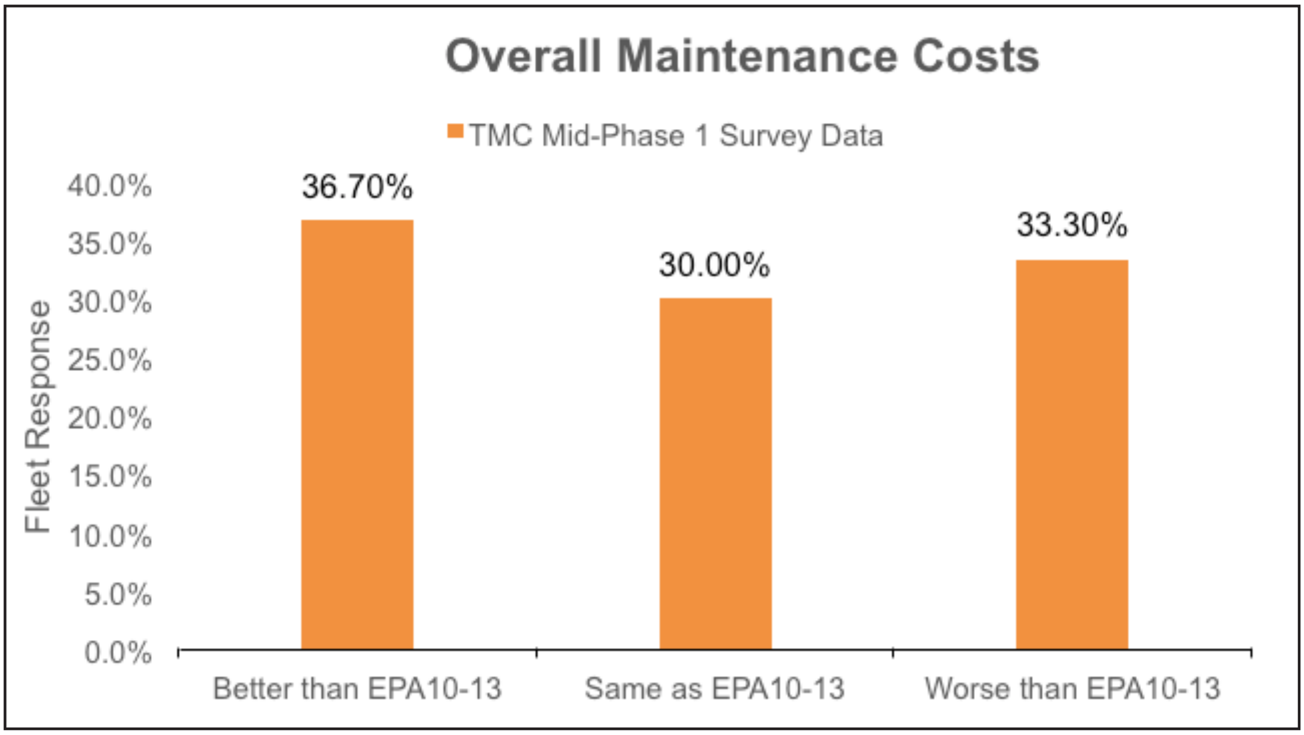
OE Support & Warranty
TMC Mid-Phase 1 Survey Data
Fleet Response
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
36.70%
50.00%
13.30%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13



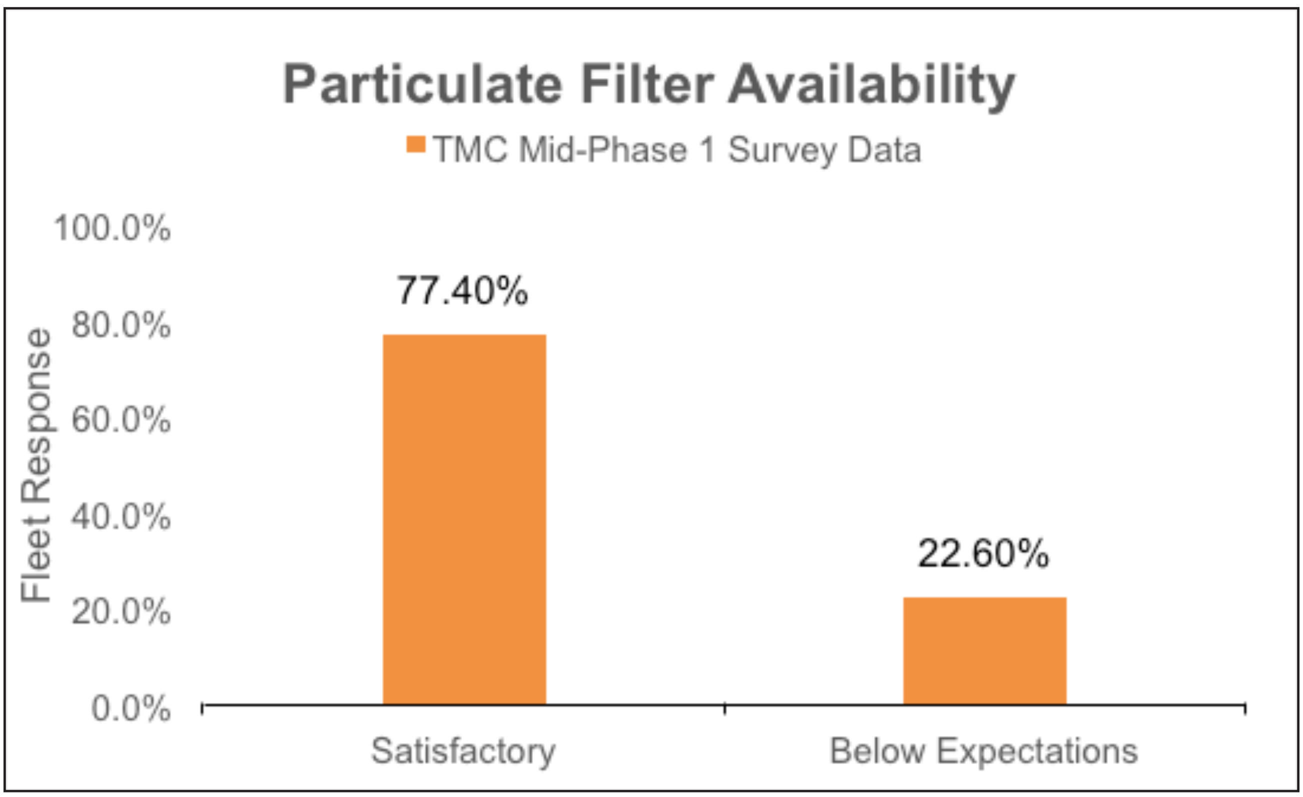
Backward Compatability
of Maintenance Components
Fleet Response
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
13.80%
65.50%
20.70%
TMC Mid-Phase 1 Survey Data
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

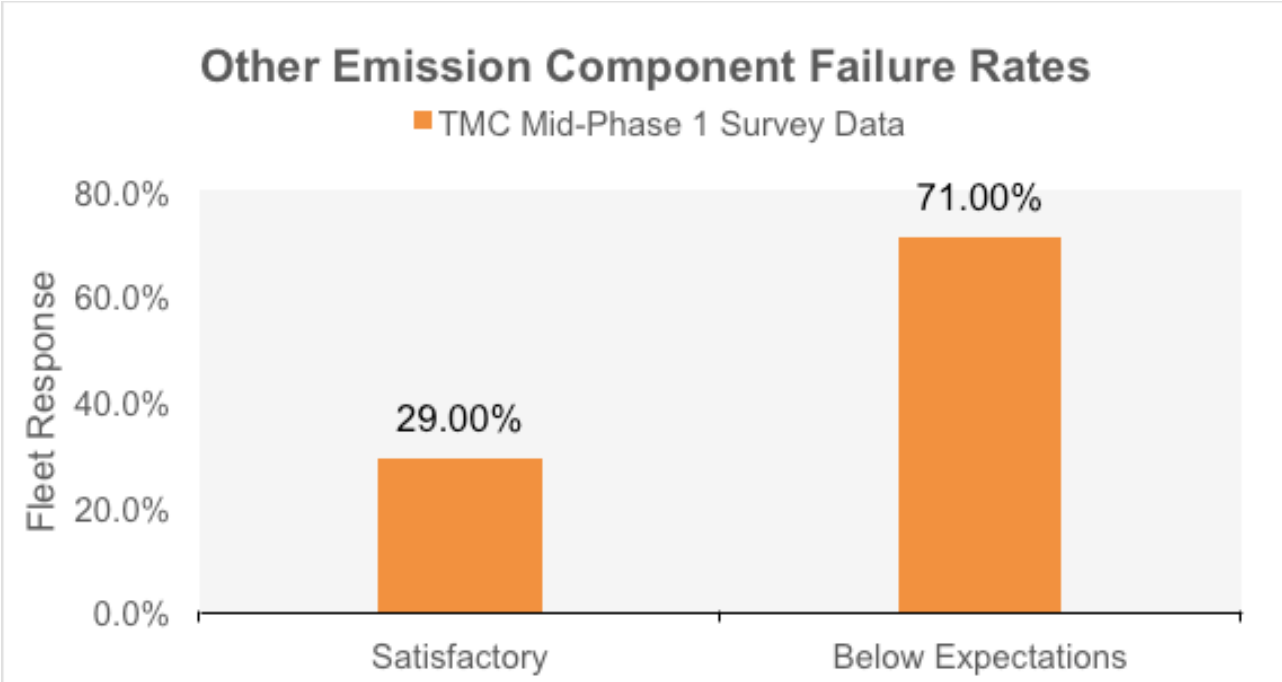

Requirement of New Maintenance Tools
TMC Mid-Phase 1 Survey Data
Fleet Response
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

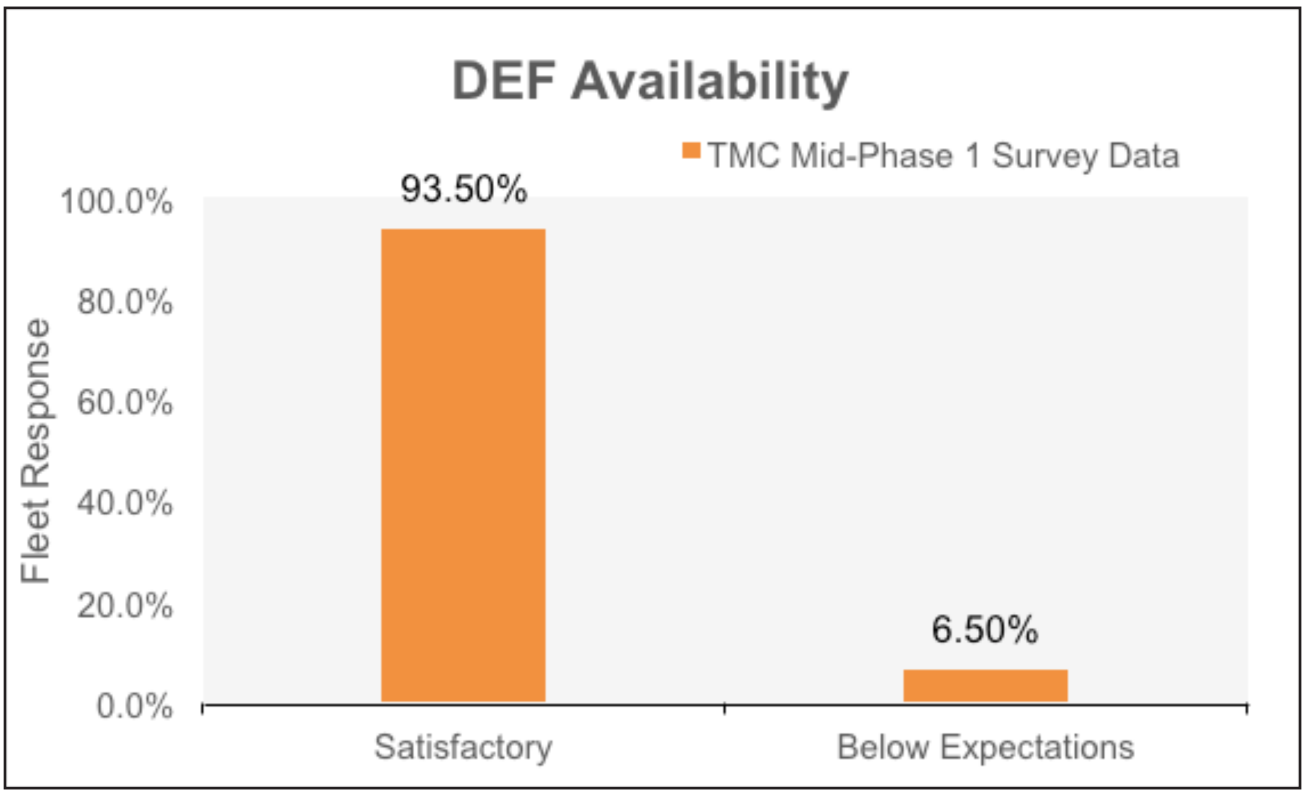

Serviceability & Ease of Diagnostics
TMC Mid-Phase 1 Survey Data
Fleet Response
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Better than EPA10-13
Same as EPA10-13
Worse than EPA10-13

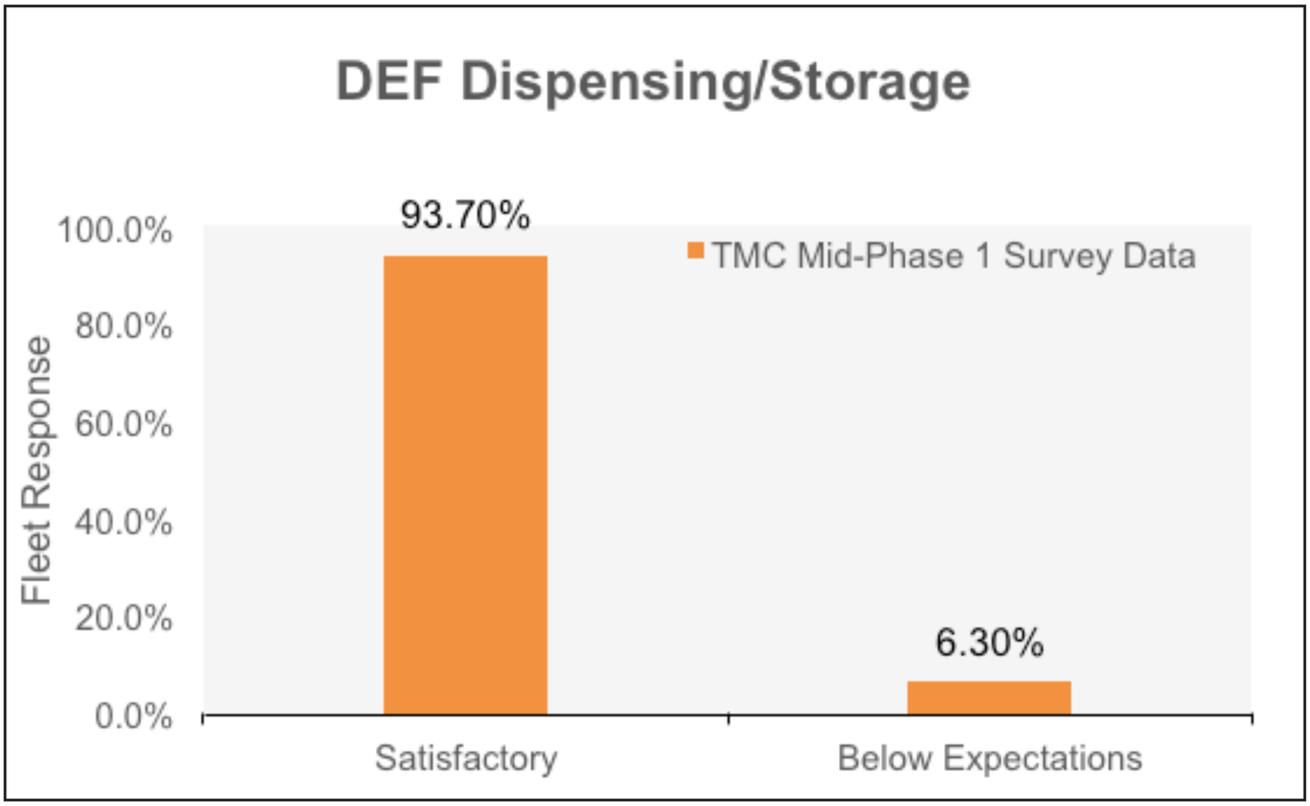


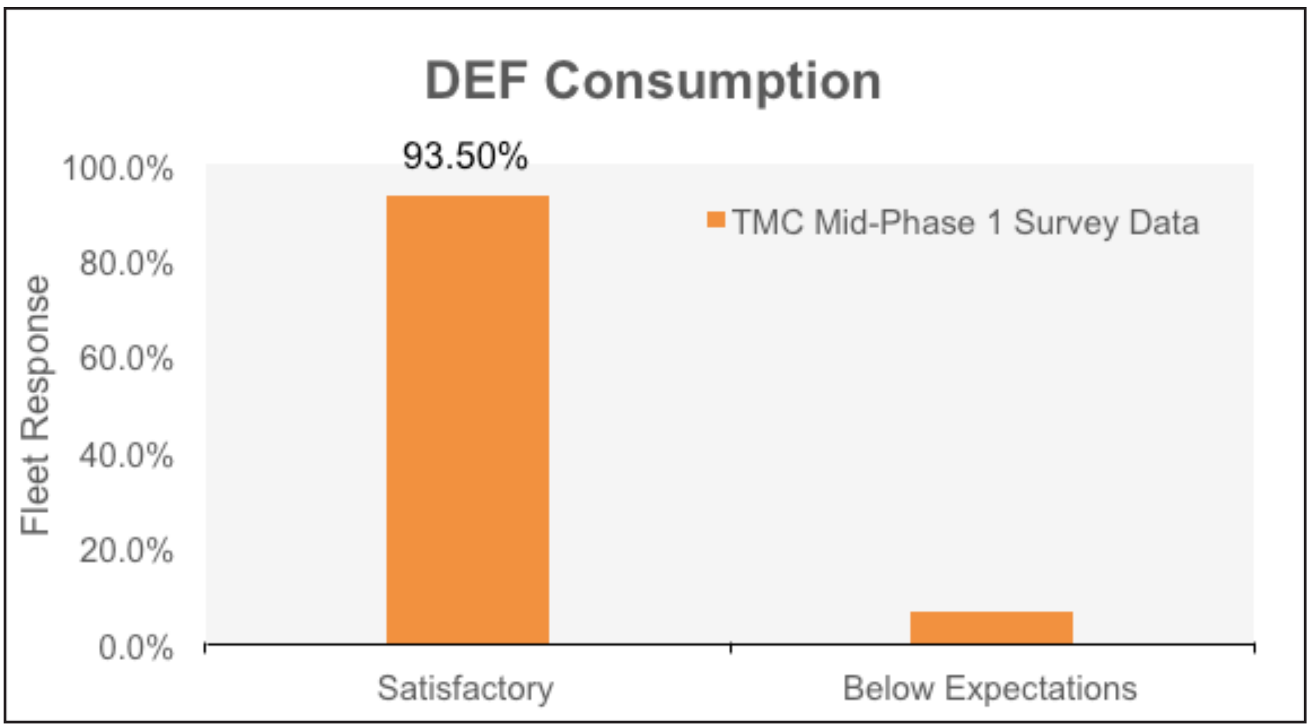
Q7. Based on your fleet's experience since the beginning of Phase 1, has your experience with the following been satisfactory or below expectations?



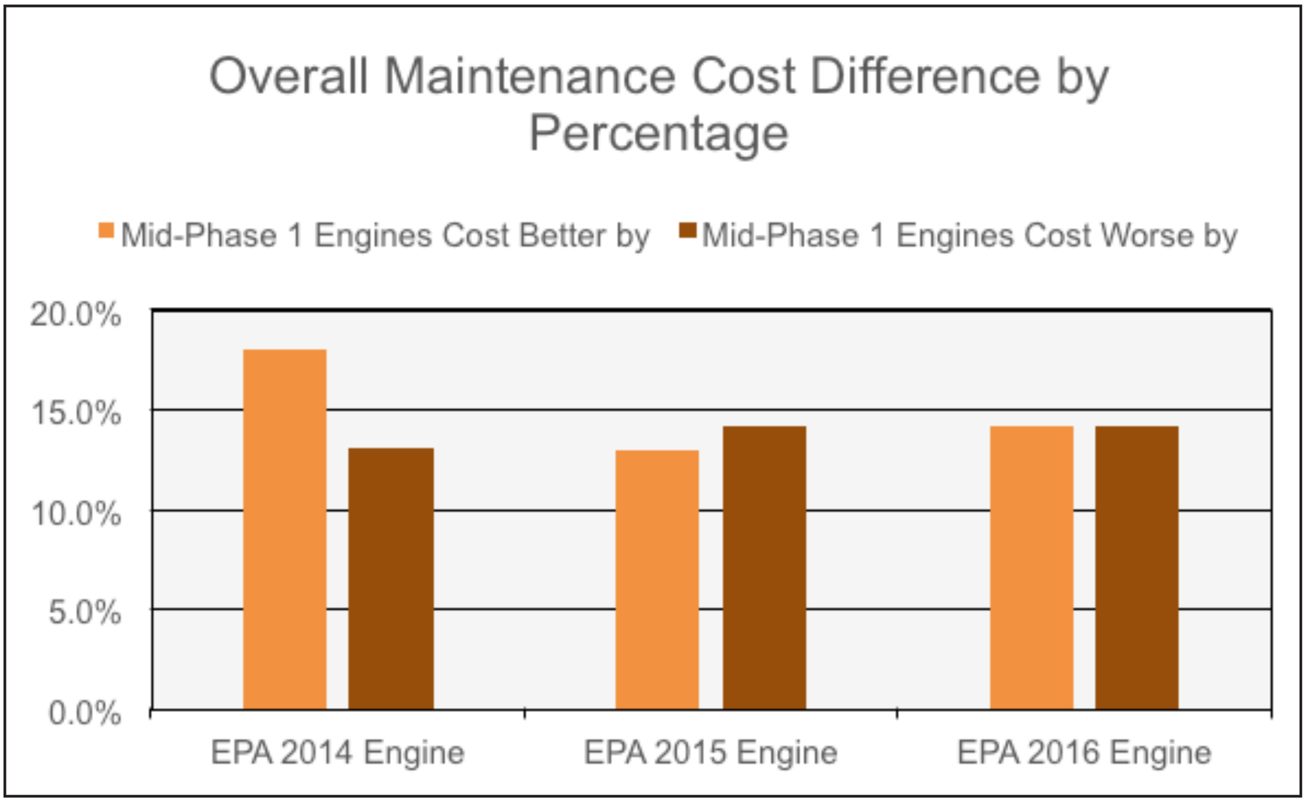

Other Emission Component Failure Rates
TMC Mid-Phase 1 Survey Data
80.0%
60.0%
40.0%
20.0%
0.0%
Fleet Response
29.00%
71.00%
Satisfactory
Below Expectations


DEF Availability
TMC Mid-Phase 1 Survey Data
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Fleet Response
93.50%
6.50%
Satisfactory
Below Expectations


DEF Dispensing/Storage
Fleet Response
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
93.70%
6.30%
TMC Mid-Phase 1 Survey Data
Satisfactory
Below Expectations


DEF Consumption
Fleet Response
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
93.50%
TMC Mid-Phase 1 Survey Data
Satisfactory
Below Expectations

Q8. Expressed as a percentage, how did your overall maintenance costs for each Phase 1 EPA engine differ as compared to Model Year 2010-2013 engines?



RESULTS

The GHG program includes carbon dioxide (CO_2) emission standards, as well as emission standards for oxides of nitrogen (NO_x) and methane (CH_4), and provisions to control hydrofluorocarbon (HFC) leaks from air conditioning systems. Different CO_2 and fuel consumption standards are applicable to three categories of vehicles: combination tractors, heavy-duty pickups and vans, and vocational vehicles:

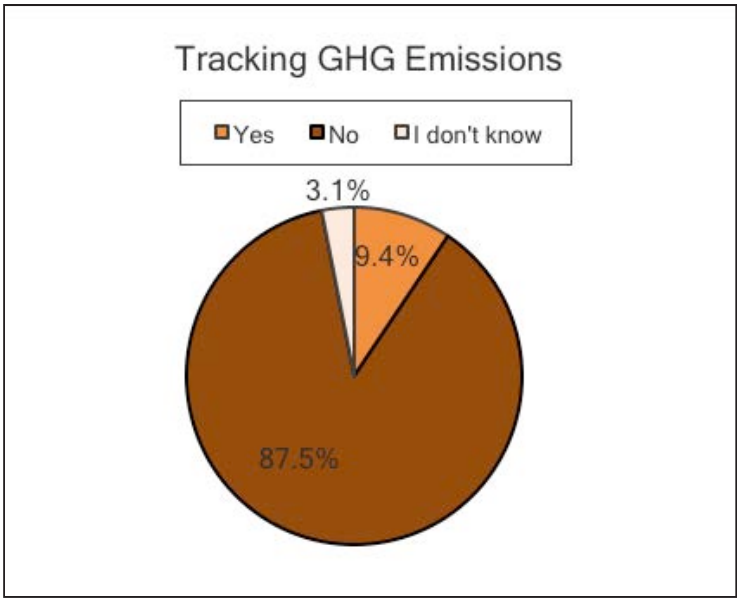
- For combination tractors, the adopted engine and vehicle standards begin in MY 2014 and achieve from 7 to 20 percent reduction in CO_2 emissions and fuel consumption by MY 2017 over the 2010 baselines.
- For heavy-duty pickup trucks and vans, the standards phase-in starting in MY 2014 and achieve up to a 10 percent reduction in CO_2 emissions and fuel consumption for gasoline vehicles and 15 percent reduction for diesel vehicles by MY 2018.
- For vocational vehicles, the engine and vehicle standards start in MY 2014 and achieve up to a 10 percent reduction in fuel consumption and CO_2 emissions by MY 2017.

The majority of vehicles covered by the regulation carry payloads of goods or equipment, in addition to passengers. To account for this in the regulatory program, two types of standard metrics have been adopted:

- Gram CO_2 per ton-mile (and gallon of fuel per 1,000 ton-mile) standards for vocational vehicles and combination tractors; and
- Payload-dependent gram CO_2 per mile (and gallon of fuel per 100-mile) standards for pickups and vans.

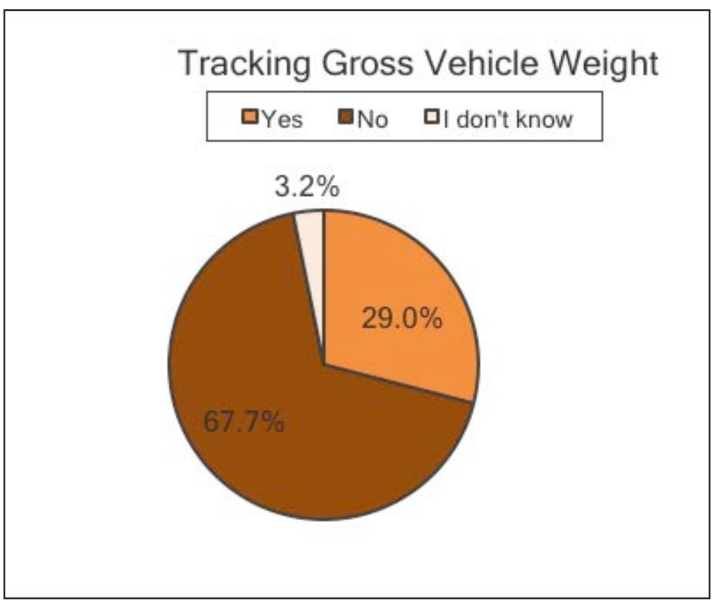
The following questions were answered to allow TMC to anonymously aggregate fleet experiences with GHG emissions to provide a scorecard for EPA and NHTSA's Phase 1:

Q9. Do you keep track of your fleet's average and/or individual units' exhaust of CO_2, NO_x, CH_4, and/or HFC (refrigerant) leaks?



NOTE: The respondents that answered "Yes" also mentioned that they use SmartWay data, telematics, and the Carbon Disclosure Project (CDP) to track their fleet's emissions.

Q10. Do you keep track of your fleet's average and/or individual vehicle gross vehicle weight during operations? If so, please briefly explain how.



NOTE: The respondents that answered "Yes" also mentioned the following:

- Electronic Bill of Lading data.
- Fleets receive a weight or scale ticket that get paid by the ton, foot, or barrels per mile.
- Auto haulers most always are loaded to max weight limit.
- Fuel haulers and bulk carriers are either loaded full or empty, both recorded prior and post-delivery.
- Some fleets collect size and weight data before loading.

Q11. If known, please provide your fleet's average annual CO_2 exhaust amount.

One respondent answered 1003g /1000km for Combination Tractors.

NOTE: Thirty-three respondents skipped this question. The answer choices were for Combination Tractors, Heavy-Duty Pick-Up Trucks and Vans, and Vocational Vehicles (per Phase 1 scenarios).

Q12. If known, please provide your fleet's average annual NO_x and CH_4 exhaust amount.
For tractors and vocational vehicles, one respondent answered 2.9 g /1000 km and another respondent answered 320 kg per vehicle. One respondent answered 50 kg per vehicle for heavy-duty pick-up trucks and vans.

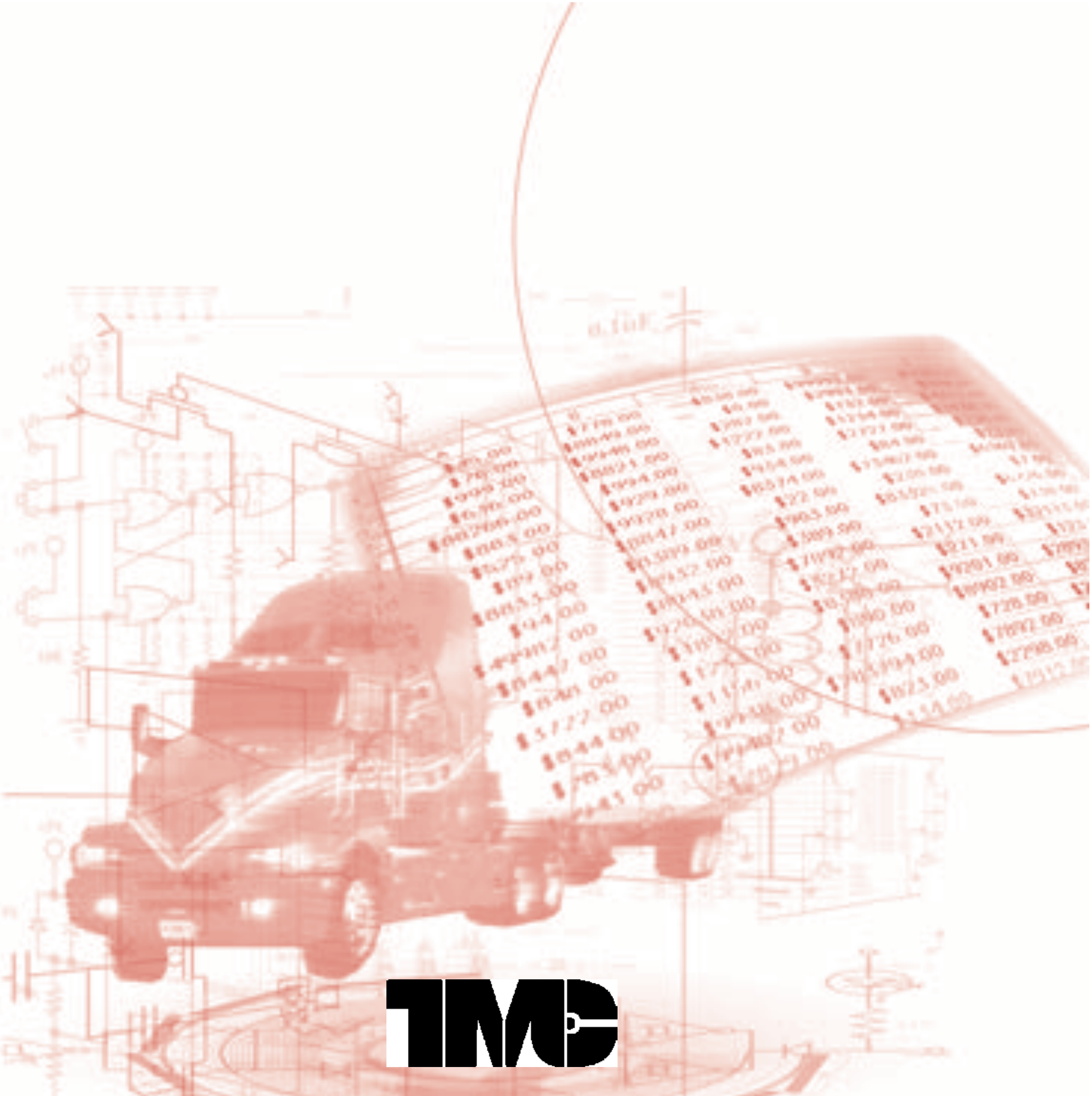
NOTE: Thirty-three respondents skipped this question. The answer choices were for Tractors and Vocational Vehicles, and Heavy-Duty Pick-Up Trucks and Vans (per Phase 1 scenarios).

Q13. EPA has adopted standards to ensure that low-leakage components are used in air conditioning systems designed for heavy-duty pickup trucks and vans, and semi-trucks. The standard for larger A/C systems (capacity above 733 g or 1.6 lbs.) is measured in percent total refrigerant leakage per year. If known, please provide your fleet's average annual percentage of displaced refrigerant. This can be recorded by your purchased amount of refrigerant replenishment rate.

Respondent answers included:

- 35 lbs.,
- two percent,
- 12 lbs., and;
- less than one percent.

NOTE: Thirty respondents skipped this question.



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