HIGHER FUEL ECONOMY
WORKING FOR FLEETS

A PAYBACK ANALYSIS: THE BUSINESS CASE FROM HIGHER FUEL ECONOMY STANDARDS IN TRUCKS AND BUSES

A CALSTART REPORT

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PREFACE

This report was researched and produced by CALSTART, which is solely responsible for its content. The report was prepared by CALSTART technical staff including Ted Bloch-Rubin, Jean-Baptiste Gallo, Steve Sokolsky and Alycia Gilde, with review by Bill Van Amburg.

Funding for this work was provided by the Energy Foundation. Assistance with fleet requirements was provided by fleet members of the National Association of Fleet Administrators (NAFA).

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There is a payback from proposed higher fuel economy rules, addressing a core fleet concern.

EXECUTIVE SUMMARY

Higher fuel efficiency standards for trucks and buses now being considered by the federal government will save fleet-dependent businesses money – even when businesses must spend more up front to purchase more fuel-efficient vehicles. Put another way: there is a payback from proposed higher fuel economy rules, addressing a core fleet concern.

This is the core finding of the report, **Higher Fuel Economy – Working for Fleets**. Other key findings include:

- A high percentage of fleet managers – 87 percent of those surveyed – support increased fuel economy rules.
- The higher cost of fuel economy technology is the biggest worry for fleet operators from such rules, but 89 percent said they would pay higher costs upfront if it led to overall savings.
- Fleet operators are concerned about reliability and maintenance costs and want to see better data from manufacturers on these issues.
- Payback periods are largely dependent on how vehicles are used and their mileage driven or engine hours, but the report documented reasonable payback periods in all but a few cases.
- Normal multi-year fleet vehicle turn-over periods and the long-lead time of the proposed rules will limit risks to fleets.

The report is based on business case evaluations of projected vehicle purchase and operations across a wide variety of truck types and usage, using a Modified Life Cycle Cost (LCC) model validated by real-world fleet operators. While there were variations in the benefits seen from truck type to truck type and from truck use to truck use, the core results were clear: more aggressive fuel economy standards for trucks and buses will help fleet-based businesses' bottom lines.

"In our business fuel economy is important; we use modeling that shows the expected fuel savings and the expected carbon footprint." –National services fleet operator

REPORT GOAL CALSTART developed this report to determine if aggressive fuel economy standards could provide benefits to fleets based on their business practices. With the assistance of the National Association of Fleet Administrators (NAFA), CALSTART first validated the key metrics that go into a LCC model based on actual fleet practice, then modified the model to account for unknown elements, such as future maintenance costs, and produced a fleet payback calculation.

CALSTART used the model to evaluate whether a fleet could expect to see a positive payback, within acceptable business timeframes, from high efficiency vehicles that significantly reduced fuel use. The analysis is based on a selected range of technologies and their projected costs which appear able to achieve the higher efficiencies (up to 40 percent reduction in fuel use) expected by 2025 and tailored to different vehicle-use profiles.

REPORT CONTEXT The need to cut carbon emissions is especially important in the transportation sector, which is responsible for nearly a third of national greenhouse gas emissions and whose emissions are increasing more than any other sector. Increased vehicle efficiency is one of the primary tools for cutting emissions. Recent federal rules call for a doubling of efficiency in light-duty vehicles (passenger

A critical question for truck users is whether they can afford to purchase and use the new, more efficient technologies.

cars and pickup trucks) by 2025 and this has set a high bar for new medium- and heavy-duty vehicle rules as the Environmental Protection Agency (U.S. EPA) and the National Highway Traffic Safety Administration (NHTSA) considers Phase II fuel economy regulations trucks and buses.

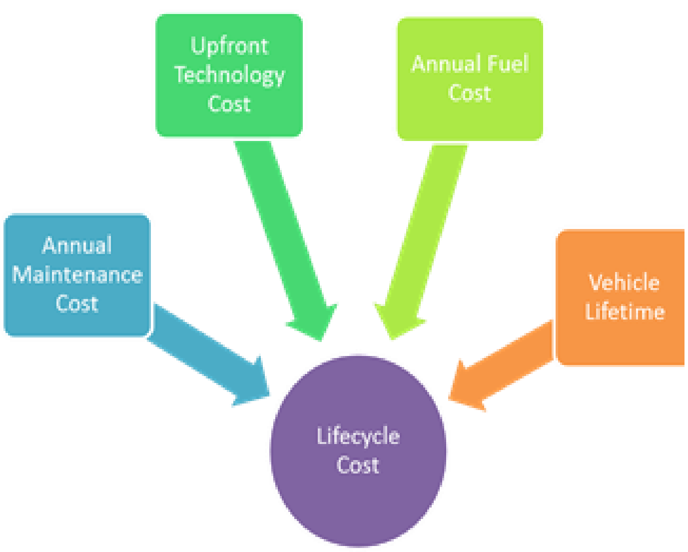
But because trucks and buses are vital work tools for businesses across the nation, carry the bulk of America's freight, and provide critical local services, the cost of meeting these proposed regulations matter. For truck users, the critical question is whether or not they can afford to purchase and use the new, more efficient technologies that stronger regulations might encourage.

> *"Fuel economy improvement means a lot more than just the cost of fuel: You don't have to refuel as often, can spend more time moving product, and can reduce the administration cost behind paying fuel bills." –Produce delivery fleet*

FLEET SUPPORT FOR EFFICIENCY In gathering data for this report, fleet managers generally expressed support for higher fuel efficiency. But they also shared concerns about potential costs. Eighty-seven percent of fleets surveyed said that they would support regulations that call for higher fuel economy. Although 86 percent of fleets said that the upfront cost of a new vehicle is the biggest concern when making a purchasing decision, 89 percent also said that they would be willing to pay a higher upfront cost as long as there were net cost savings over the life of a vehicle.

REPORT APPROACH Figure ES-1 presents the high level metrics that make up a fleet-validated Life Cycle Cost (LCC) Model. The Modified LCC model used to generate the fleet payback calculations for this report was built on this structure, but relied solely on those elements for which reasonable, category-specific data were currently available. A key unknown element was future maintenance costs.

Figure ES- 1: Key metrics for a life cycle cost (LCC) model



Using vehicle segments developed by the California Hybrid, Efficient and Advanced Truck (CalHEAT) roadmap, vehicle use profiles were identified – such as long-haul 18-wheelers, local delivery vans, large pickup trucks used in construction, etc. – and interviews with fleet managers provided real-world details on operations. To best capture the representation of fleets that will be affected by the new Phase II rules, CALSTART collaborated with NAFA fleets to collect feedback from a broad range of fleet types and examined seven different vehicle categories and applications of commercial and public vehicles.

The vehicle categories included:

High-mileage operations could see investments in fuel-efficient technologies paid back in as little as nine months.

1. Heavy-Duty Over-the-Road
2. Heavy-Duty Short-Haul/Regional
3. Medium-Duty Urban
4. Medium-Duty Rural/Intra-city
5. Medium-Duty Work Site Support
6. Class 2B Gasoline Trucks and Vans
7. Class 2B Diesel Trucks and Vans

Special focus was put on obtaining fleet-validated annual fuel consumption data, and vehicle usage data which was expressed in miles or engine hours. Then different technology packages, such as aerodynamics, engine improvements, start-stop systems and advanced transmissions that were applicable to individual vehicle use profiles, were selected as reasonable to provide theoretical fuel savings for the use profile in question. Fleets were then given the opportunity to comment on the results associated with their particular use profiles. This provided important feedback on the feasibility of adopting various technologies and also revealed ancillary benefits of fuel economy improvement for their businesses. These can include reduced fuel tank sizing, fewer fueling events, and less back-office billing activity.

REPORT FINDINGS Our analysis of higher fuel economy standards showed that the fleets with the highest mileage and fuel use would realize the greatest savings in fuel costs and the fastest vehicle payback. For example, fleets that operate Class 8 tractors – which include the 18-wheelers – often travel more than 125,000 miles per year. With diesel fuel prices projected to rise over the next 10 years, higher fuel economy standards could see these fleets saving up to $20,000 per year/per truck in fuel costs. These high-mileage operations could see their investments in fuel-efficient technologies paid back in as little as nine months. Our findings echo other studies made of this sector.[1]

Figure ES- 2 illustrates how vehicle usage directly affects payback in new technologies for Class 8 trucks.

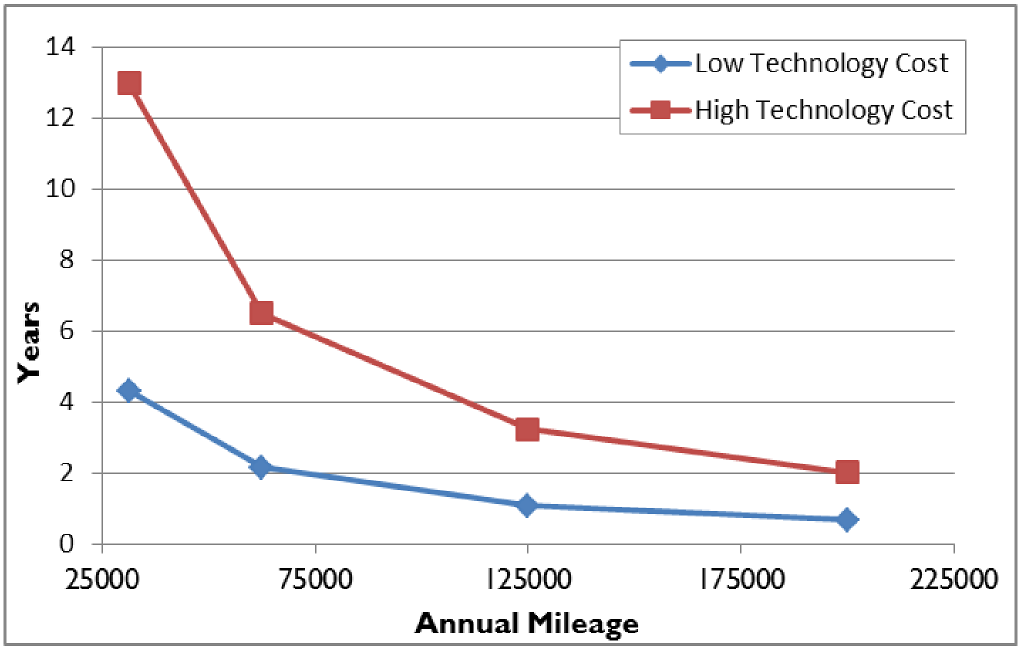


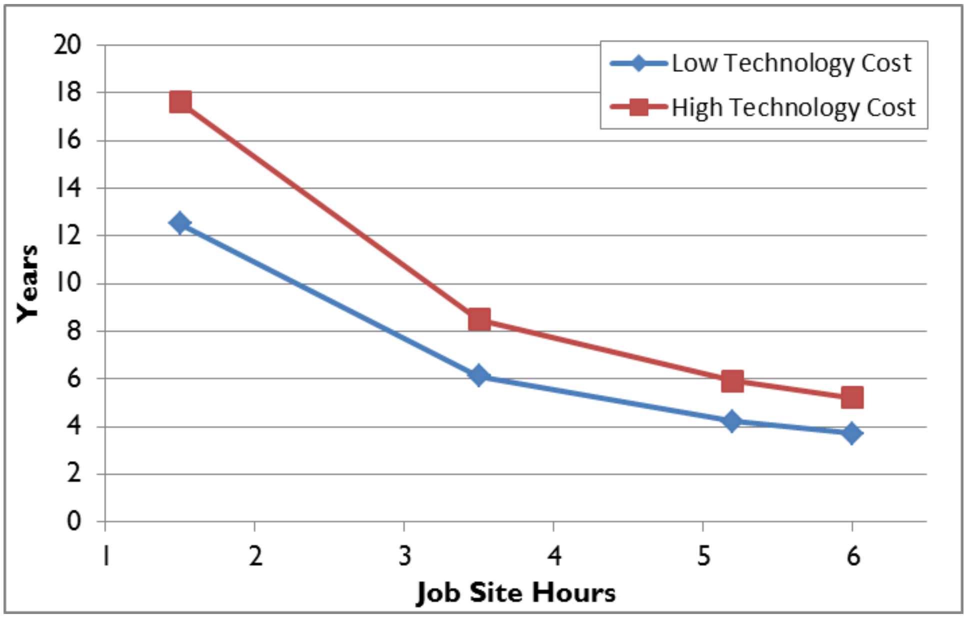
Figure ES- 2: Payback curves for heavy duty over-the-road vehicles

[1] Meszler, Dan, Lutsey, Nic, Delgado, "Cost effectiveness of advanced efficiency technologies for long-haul tractor-trailers in the 2020-2030 timeframe", ICCT, April 21, 2015

Each fleet is different. But in every scenario we modeled there is a reasonable business case to be made for higher fuel economy in trucks and buses.

Work trucks that do not have high mileage can also see fuel cost benefits from high-efficiency vehicles. For example, Class 3 trucks such as the Dodge Ram 3500 and Ford F-350 that travel 25,000 miles per year could see fuel cost savings up to $1,570 annually per truck with payback in as little as 1.1 years. The report details different vehicle operational scenarios such as utility trucks, with low mileage but substantial amounts of annual fuel consumption while idling at worksites. These Class 4 trucks can see savings of up to $9,000 in annual fuel costs and a payback of 3.5 years by incorporating plug-in hybrid technologies and engine configurations that allow for "engine-off" mode at worksites. Payback on these vehicles is highly dependent on the job site idle hours of a given duty cycle, as shown in Figure ES- 3.

Figure ES- 3: Payback curves for medium-duty work site support vehicles



Finally, trucks that run on lower cost gasoline can also see meaningful fuel cost savings and short payback periods. The most predominant vehicles in fleet operations are Class 2B pickup trucks and cargo vans. Based on our discussions with fleet operators, new fuel economy rules could increase real-world fuel economy in Class 2B vehicles from what fleet operators experience now to a real-world 17 MPG. Performing the analysis for fleets with this vehicle class and MPG, fuel cost savings resulted in $1,600 per vehicle per year and a payback period of 1.3 years.

For all the vehicle categories analyzed in this report, fuel cost savings and payback will depend on vehicle miles traveled, fuel used, and the cost of fuel. Nonetheless, this report concludes that future technologies responsible for a near doubling of fuel economy across different platforms can directly benefit fleet-based businesses, as shown by the payback results calculated using the Modified LCC model.

Each fleet is different. But in every scenario we modeled there is a reasonable business case to be made for higher fuel economy in trucks and buses. When this approach is coupled with fleets' normal vehicle turn-over cycle, which vary from four to more than 10 years, fleet risk from transitioning to such vehicles is found to be low. Most fleets will also have the opportunity to deploy early purchases into operational applications with the best payback (generally higher mileage or fuel use applications).

1. BACKGROUND AND INTRODUCTION

"Higher Fuel Economy – Working for Fleets," outlines the business case and cost benefits of cleaner, high-efficiency vehicle technologies that can result from new fuel economy standards that will be enacted by the United States Environmental Protection Agency (EPA) and the National Highway Transportation Safety Administration (NHTSA). The proposed standards aim to greatly improve fuel efficiency while reducing carbon emissions from on-road medium to heavy-duty trucks and vocational vehicles. These "Phase II" rules will build off earlier regulations and add stronger reduction goals for the period of 2021 – 2027.

During the report development process, CALSTART established an assumed fuel economy goal around which to base its analysis. It then reviewed existing cost projections and technology readiness reports to assemble a portfolio of potential technologies that could provide such fuel economy gains and what they might cost in low and high cost scenarios. The team then interviewed and surveyed numerous fleets of different vocations on their vehicle use profiles and experience with high-efficiency vehicle technologies. CALSTART identified fleets from a diverse set of vocational duty cycles including: over-the-road (OTR), short haul/regional delivery, refuse collection, urban, rural, worksite, and Class 2B, providing a business case for each application and duty cycle.

The goal of this report is to determine if aggressive fuel economy standards could provide benefits to fleets based on vehicle technology cost and business practices. To determine this we identified the key cost elements that go into purchasing decisions for fleets and created an ownership model that could identify economic feasibility for investments in new high-efficiency vehicle technologies. Our approach looked at the potential higher costs of new technologies as a result of new fuel economy standards and ran a Modified Life Cycle Cost (LCC) model against real-world fleet profiles. By using the approach described in section 2, we reported positive fleet payback on technology investments as a result of this model.

"To our operators we say, we're not trying to affect what you do, but new technology might affect how you do it." –Regional utility fleet manager

New fuel economy standards can provide an impetus and an opportunity for fleets to institute best practice methods for planning and managing vehicle procurement, including the use of life cycle assessment. In addition, business-savvy fleets that use strategies such as optimized vehicle procurement ("right-sizing" vehicles for specific operations), smart route planning (assigning appropriate vehicles to individual routes), and stakeholder training (driver, fleet maintenance, and management) can further increase the positive economic and operational benefits of vehicle fuel efficiency gains, making Phase II regulations work for them.

2. APPROACH

Section 2 illustrates the development of a Modified Life Cycle Cost (LCC) model and the resultant fleet payback analysis which was used to estimate cost saving benefits of higher fuel economy vehicles. CALSTART collaborated with the National Association of Fleet Administrators (NAFA) to conduct a survey amongst NAFA membership (45 fleets responded) representing a cross section of regions and applications to identify important cost ownership elements. One-on-one interviews with several fleets of various sizes and vocations were also conducted to validate calculations and to obtain inputs for different vehicle categories.

2.1 Life Cycle Cost Model

Fleets use a variety of tools to make vehicle purchasing decisions on an annual and long-term basis, one of which is the Lifecycle Cost model (LCC). Figure 2-1 below illustrates several critical elements that impact LCC.

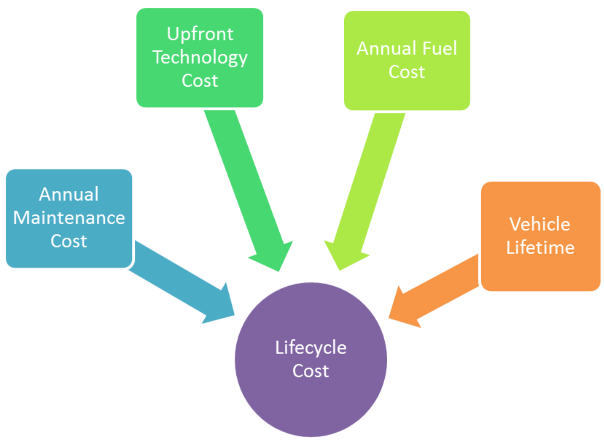


Figure 2-1: Elements contributing to a life cycle cost model

Upfront technology cost and annual fuel cost were the key metrics used in the fleet payback calculations which resulted from CALSTART's Modified LCC approach. Lifecycle cost, with an implied ownership period, can provide a more comprehensive argument for purchasing decisions than simple payback alone. Analyzing vehicle technologies beyond the upfront cost was not possible for this study, but using a model like that shown in Figure 2-1 can help fleets make more effective decisions for purchasing advanced vehicle technologies.

2.2 Fleet Survey

CALSTART relied on its network of fleet and industry experts throughout the research and analysis process, from initial conversations with fleet managers to a widely-distributed online survey with members of the National Association of Fleet Administrators (NAFA). Fleet managers provided feedback on survey questions that would help identify the most important input elements to a Life Cycle Cost (LCC) model in addition to decision-making metrics for new vehicle purchases. The survey (questions and answers reproduced in Appendix A) was also designed to obtain fleet demographic details and reactions to the forthcoming Phase II standards.

This survey was distributed to an internal CALSTART database of advanced vehicle purchasers within California, NAFA member fleets, and known industry contacts nationwide, receiving a total of 45 in-depth responses during a three week period. Survey respondents represented small and large fleets nationwide; Figure 2-2 below highlights this diversity.

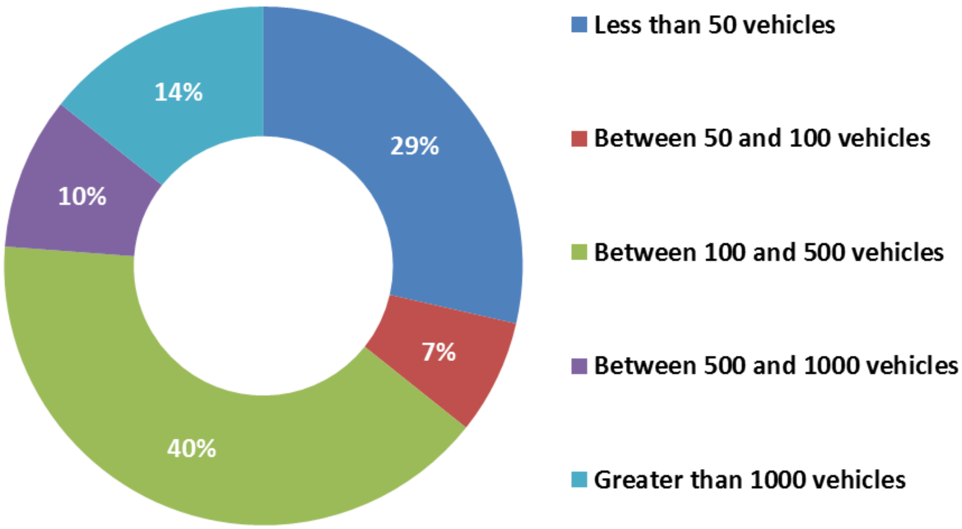


Figure 2-2: Fleet size of survey respondents

As Figure 2-2 demonstrates, the majority of survey respondents either represented smaller fleets of less than 50 vehicles or medium to larger fleets of between 100 and 500 vehicles. Figure 2-3 below gives a rough indication of the broad geographic response to this survey.

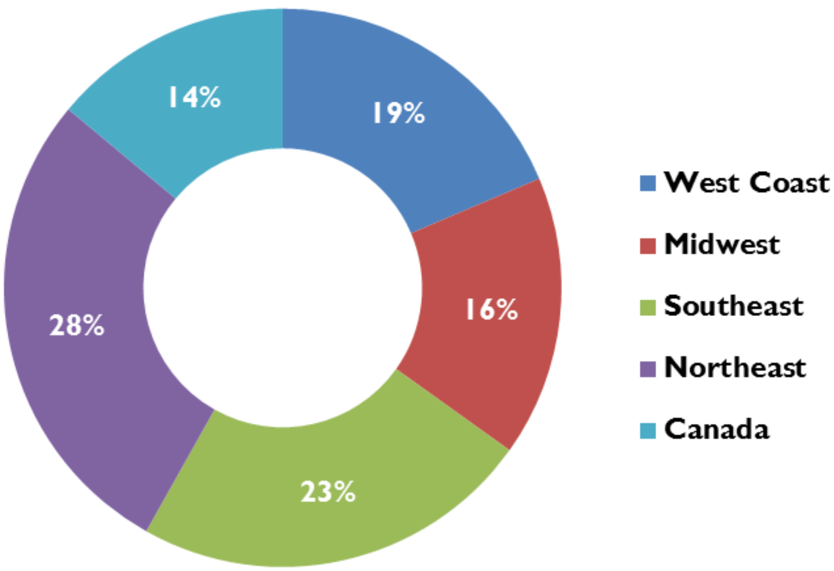


Figure 2-3: Geographic location of survey respondents

While the respondents do not represent a significant percentage of the total North American fleet makeup, their selection for demographic and geographic diversity provides an important national perspective as the survey responses demonstrated common trends and consensus across all fleets.

For example, survey responses presented a common trend for the primary elements that are required in an LCC model. Figure 2-4 presents the rating of importance for each element in an LCC model.

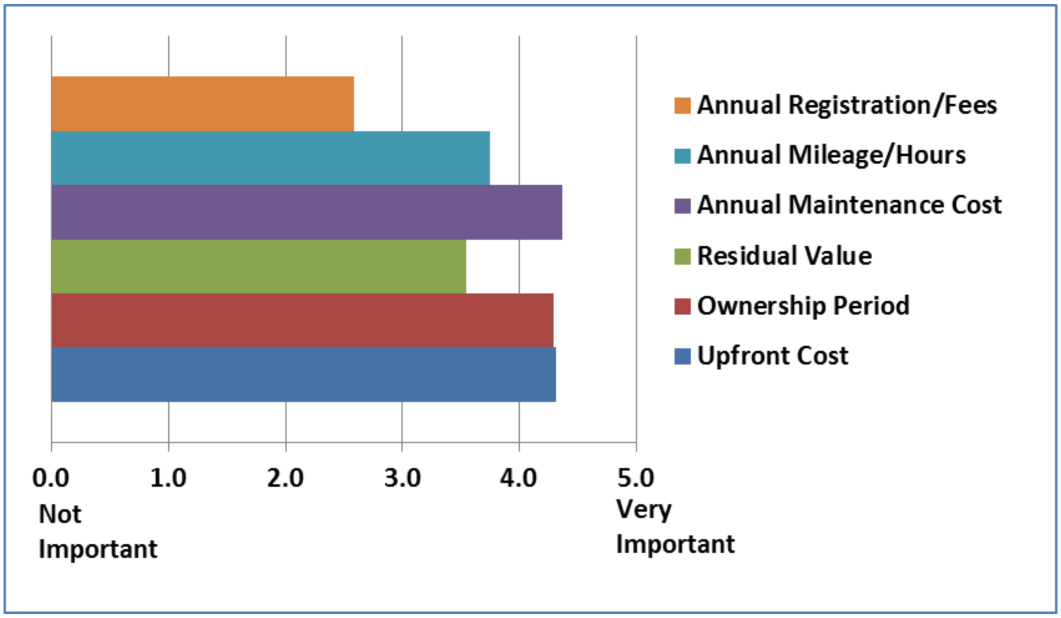


Figure 2-4: Importance rating for Life Cycle Cost (LCC) Model elements

The four highest rated LCC elements were annual mileage, annual maintenance cost, vehicle ownership period, and upfront cost. The residual value of the vehicle can be very important for some fleets because their new purchases are routinely given second-life through auctions and other sales, for example, after a lease term is completed. There is a subset of fleets however that drive their vehicles “into the ground” and are forced to crush them for scrap metal at vehicle end-of-life. These four elements were reviewed as the basis of an LCC model, then down-selected for fleet validation through a series of interviews and model iterations.

Another major finding from the fleet surveys was that there are clear metrics that are used to support vehicle purchase decision-making. Respondents were asked to rank in the order of importance the metrics used in evaluating vehicle costs; Figure 2-5 below shows their combined opinions.

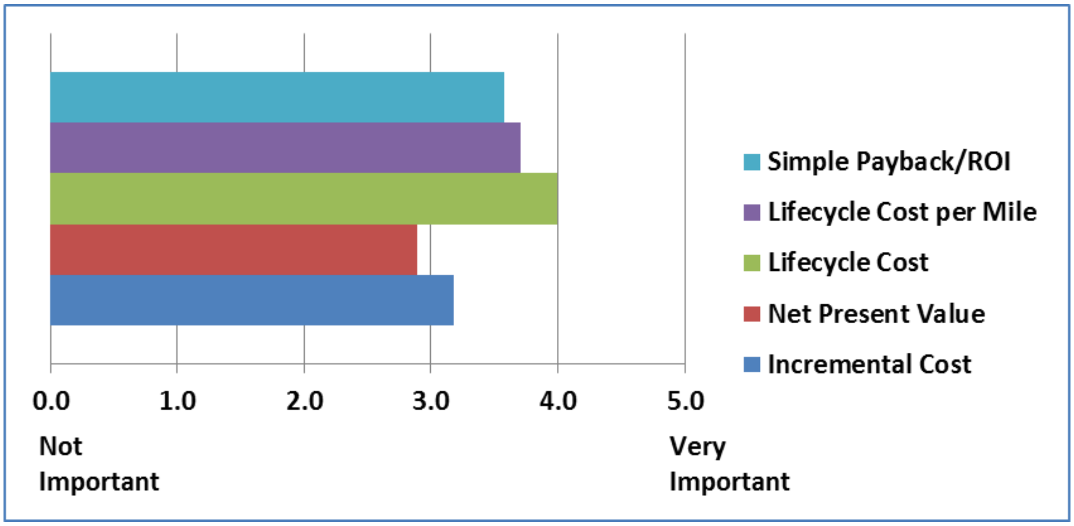


Figure 2-5: Importance rating of vehicle purchase decision metrics

Interestingly, fleets rated the two life cycle cost metrics as most important in making vehicle purchase decisions, perhaps reflecting a shift away from simple incremental cost analysis. This is important to note with regard to the advanced technology vehicles that Original Equipment Manufacturers (OEMs) will begin offering to meet aggressive Phase II standards. These vehicles will likely carry a higher upfront cost than contemporary conventional vehicles, but analysis and decision-making with route-specific life cycle cost metrics could provide fleets with adequate data to intelligently plan their phased adoption.

Aggregated fleet comments provided insight into the ratings shown in Figure 2-5. To many fleets, the actual break-even point makes a difference on whether the initial investment can be made. But simple payback does not tell the whole story. Life cycle cost analysis should be a primary decision factor for new purchases, and fleets who support it say it has secondary benefits such as enhanced vehicle cost control and management on a yearly basis throughout the vehicle lifetime. Others caution that cost savings must be attainable and significant in comparison to conventional vehicles. Advanced technologies may require expensive repairs, which can severely detract from any potential cost savings from reduced fuel consumption. Fleets agreed that the life cycle cost of these advanced vehicles should be less than other alternatives to offset the initial investment in the incremental vehicle cost; some require substantially lower cost for their specific applications.

Grounding these metrics are the broader survey responses to questions regarding support for effective regulation and openness toward life cycle cost analysis of new vehicle purchasers, as well as an indicator for significant market adoption of advanced vehicles. Figure 2-6 below shows the breakdown of responses to these three questions.

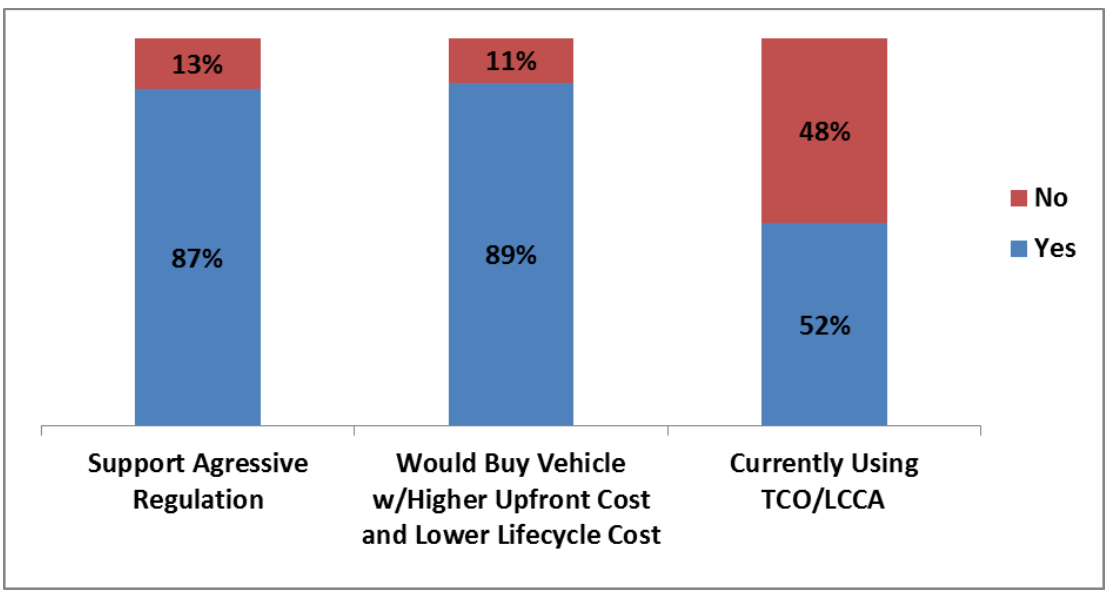


Figure 2-6: Breakdown of survey responses to current behavior and future purchasing

An overwhelming majority of the fleets surveyed both support aggressive regulation that would require manufacturers to provide higher fuel economy vehicles and would consider purchasing such vehicles at a higher initial premium provided their life cycle cost were lower than a conventional counterpart. Results also indicated that nearly half of respondents are not currently making purchase decisions based on Total Cost of Ownership (TCO) or analysis like the LCC model in this report, for a variety of reasons, including poor baseline data, lack of analytics resources, and familiarity with status quo manufacturers. There is a tremendous opportunity to reach out to fleets represented by nearly half the survey respondents, with the eventual hope that the LCC usage approaches the other two categories shown in Figure 2-6.

Fleets identified numerous explanations for supporting regulation mandating high fuel economy vehicles from manufacturers; the most basic is the lower operating cost of such vehicles in comparison to conventional options. Aggregated comments identified fuel consumption as a high operating cost that can be acted upon. Fleets believe the relatively low price of oil is causing short-sighted purchase decisions wherein lower upfront cost is given precedence to advanced technologies with fuel economy improvement. Many believe this ill-conceived tradeoff will harm future operations, when the price of oil returns to its steady increase, by leaving fleets with more, higher-consuming vehicles.

Yet while lower operating costs should be achievable, there are concerns to be heeded for advanced technology vehicles to realize their full potential. Due to highly variable on road and work site duty-cycles, special care must be taken to ensure that fleets have adequate purchasing options for higher fuel-economy vehicles that are applicable to their drive-cycle and fueling capability. Additionally, unreliable vehicles create unforeseen costs in downtime; therefore manufacturers need to ensure technologies do not reduce reliability and that their fuel economy goals are reachable, with deployments neither cost nor time-prohibitive to fleets. A regulatory approach to address this concern would be a stair-step roll-out of new technologies, ensuring that fleets are not forced to dedicate major resources to accommodate large numbers of new vehicles "working out the kinks." For fleets that buy used vehicles, new technologies are understandably of concern because their long-term maintenance trends may be unknown or unpredictable. With proper development and real-world testing of advanced technologies, manufacturers could help assuage some of the long-term reliability fears that most fleets have with new or used vehicles.

Of all the fleets surveyed, few referenced either the environmental or national security benefits inherent in higher fuel economy vehicles. Some argued that all should have access to clean air, and that emission reduction as a result of increased fuel economy is a humanitarian goal benefiting everyone. Reduction in fossil fuel consumption carries the additional benefit of reducing dependency on volatile foreign oil markets. These are the only non-business case oriented comments provided by the survey respondents, underscoring the 87 percent that support regulation primarily to reduce their fuel use for business case reasons.

2.3 Interviewed Vehicle Classes

Fleet interviews were down-selected based on vehicle use profile representatives that helped us validate the fleet payback calculations across medium and heavy-duty commercial vehicle sectors. Ultimately, nine fleet managers from national, regional, and local fleets were interviewed in depth to provide specific feedback on calculation inputs and vehicle performance details across different duty-cycle and use profile scenarios. Details such as realistic annual mileage, fuel economy, and vehicle lifetime were key in evaluating current and future fuel economy. The fleet managers that were interviewed also helped to identify the potential Phase II vehicle technologies that would be most appropriate for their vocational business sector based on their past experience and business expectations.

The vehicle categorization used in this report is based on the research and market transformation roadmap developed by the California Hybrid, Efficient and Advanced Truck (CalHEAT) program. The CalHEAT categories were developed through an extensive survey of vehicle operational characteristics that impact technology choices driving fuel efficiency. The categories were less determined by weight than by similar use profiles. The vehicle categories are shown in Figure 2-7 below and are further described below.

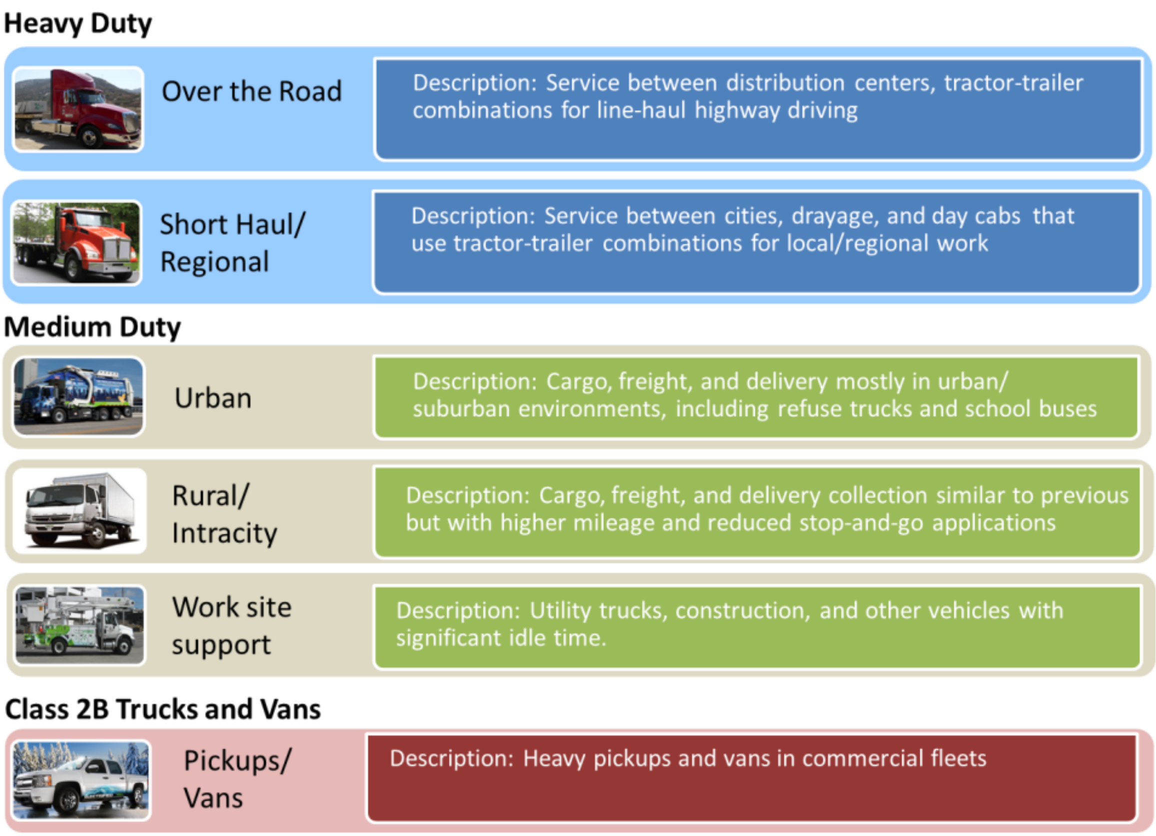


Figure 2-7: Vehicle categories designed by the CalHEAT roadmap

The six CalHEAT vehicle categories cover nearly the entire medium and heavy-duty commercial vehicle sector, though off-road heavy equipment is not included as that category is controlled under unique regulations. The goal of this categorization was to combine vehicles, regardless of exact weight rating, into groups of similar application or environment, as these factors often hold more sway in the effectiveness of an advanced technology than weight rating alone. On this basis, the team then determined the relative appropriateness of technologies to the vehicle categories shown above.

2.4 Technology Areas and Association to Vehicle Categories

There are eight broad-based technology areas around which OEMs and other suppliers could provide future fuel consumption reductions in medium- and heavy-duty vehicles. A brief description of each technology area is provided in Appendix B, while

Figure 2-8 below depicts the potential for fuel consumption reduction of each technology for the six vehicle categories previously described. While this segmentation may not directly match those of the eventual regulations, they are likely to be similar. This diagram is based on the CalHEAT assessment and interviews with fleets about the most applicable technology for their applications.

	Heavy Duty		Medium Duty			Class 2b Trucks & Vans
	Over-the-Road	Short Haul Regional	Urban	Rural Intra-city	Work Site Support	
						
Engine Optimization	●	●	●	●	●	●
Waste Heat Recovery	●	◑	◑	○	○	○
Transmission & Driveline Improvement/ Integration	●	●	●	●	●	●
Hybridization	○	◑	●	◑	●	●
Improved Aerodynamics	●	●	◑	◑	○	○
Electrification of Accessories	●	●	◑	◑	●	◑
Wheels & Tires	●	●	◑	◑	○	◑
Weight Reduction	●	●	◑	◑	◑	◑

Legend

● Provides the most potential for fuel consumption reduction

◑ Provides some potential for fuel consumption reduction

○ Provides limited potential for fuel consumption reduction

Figure 2-8: Advanced technology and vehicle category matrix for fuel consumption reduction

Not surprisingly, engine optimization, transmission and driveline improvements have the broadest applicability across all vehicle categories. Improvements to these two categories could be readily adopted in many different vehicle platforms and applications, unlike some of the more specialized advancements that will provide most benefit to the high-mileage or duty-cycle dependent applications. These include waste heat recovery, wheels and tires, and weight reduction, all of which are most effective on heavy-duty trucks that travel at highway speeds for many miles hauling freight. Technology specification for the work site support vehicle category must be very selective.

Figure 2-8 shows that the greatest number of limited-potential technology areas for any vehicle category correspond to work site support.

2.5 A Modified Life Cycle Cost (LCC) Model and Calculation Inputs

In developing the Modified Life Cycle Cost (LCC) model that ultimately resulted in fleet payback, the team decided to analyze only those elements that provided reliable and recently available technical data.

While CALSTART was able to use Phase II vehicle technology and fuel reduction estimates generated in a recent report by the Union of Concerned Scientists (UCS), we were unable to estimate any associated maintenance savings or cost information for each technology due to a lack of available data.[2] Even with the small amount of data on maintenance that was collected from the fleet interviews, there was not adequate information available to warrant calculation and comparison of LCC that would include all the elements shown in Figure 2-1. Rather, fleet payback was identified as the most meaningful LCC model output that could incorporate available data and simultaneously be least affected by maintenance-excluding analyses.

Payback is calculated from the incremental technology cost and an assumption that savings in the first year of operation will remain constant throughout the vehicle lifetime. This simplistic calculation is not impacted dramatically by maintenance costs because service issues in the first year of ownership should be rare and not overly costly. This legitimizes the focus on fuel savings and upfront cost in fleet payback calculations, though results may be more conservative than those which might include additional maintenance savings from advanced technologies. Depending on performance and reliability of the advanced technology, fleets may even experience decreased maintenance cost compared to a baseline vehicle, resulting in a shorter payback.

The key elements which remained and needed to be defined for each vehicle category were annual usage and baseline fuel consumption. Estimates shown in Table 2-1 come from discussions with industry experts and the fleet interviews. Interviewees were identified with assistance from NAFA membership and from the group of survey respondents, with the ultimate goal of obtaining real-world information for all the CalHEAT categories. Multiple interviewees indicated their use of gasoline and diesel vehicles, particularly in the lightest category, Class 2B; for this reason a seventh vehicle category was added to the CalHEAT groupings for further payback analysis. Usage values are included as either annual mileage or operating days. Fuel consumption is shown as either fuel economy (in miles per gallon) or average daily fuel consumption, depending on vehicle category.

Table 2-1: Fleet payback calculation inputs for each vehicle category

Vehicle Category	Annual Usage	Baseline (2015) Fuel Consumption[3]
HD Over-the-Road	125000 mi	6.0 MPG
HD Short-Haul/ Regional	68000 mi	6.0 MPG
MD Urban	18750 mi	8.0 MPG
MD Rural/Intra-city	37500 mi	10.0 MPG
MD Work Site Support	250 day/year	10.7 gal/day[4]
Class 2B Gasoline Trucks and Vans	25000 mi	12.3 MPG
Class 2B Diesel Trucks and Vans	25000 mi	10.5 MPG

[2] Cooke, Dave, Khan, Siddiq, Tonachel, Luke. "Fuel Savings Available in New Heavy-Duty Trucks in 2025." *Union of Concerned Scientists*. Pub Nov 2014. (4/30/15).
[3] From fleet specific interviews and other industry data.
[4] "Optimization of Hybrid Systems for Combined Driving/Stationary Duty Cycles." *Odyne Hybrid Systems*. Pub 2014. (5/12/15).

The heavy-duty over-the-road category shows extremely high annual mileage that often leads to a vehicle resale at 500,000 cumulative miles. One of the fleet managers interviewed explained that for such high-mileage vehicles, maintaining a young fleet is imperative to keeping maintenance costs as low as possible while taking advantage of the latest technologies for improved fuel economy and vehicle performance. The heavy-duty short-haul and regional vehicles are usually kept to a similar cumulative mileage threshold, though some national fleets increase their vehicle lifetime by reducing annual mileage in later years while maintaining the same cumulative mileage threshold.

For the medium-duty work site support category, CALSTART decided to base fuel consumption estimates off a daily average usage, mainly due to the diverse applications of this vehicle type. Job routes may use the same vehicle to and from a jobsite five miles from its base of operations where it then idles for four to six hours, while the next day the same vehicle may travel 100 miles between quick one-hour emergency repair sites. Calculations for estimated fuel consumption and technology savings for the work site support sector will be reviewed in-depth in Section 3.1.2. The gasoline class 2B vehicles showed higher fuel economy than their diesel counterparts most likely due to the route assignment differences between these vehicle types, not due to the specific efficiency of the engines. Interviewees indicated that their gasoline trucks and vans tended to conduct higher-speed less urban routes than diesel vehicles in Class 2B, which generally result in less idling and higher overall fuel economy.

2.6 Fleet Payback Analysis

With the Modified Life Cycle Cost (LCC) Model inputs developed in Section 2.5, fleet payback was calculated for all seven vehicle categories. The Modified LCC calculations evaluated the potential cost impact of assumed Phase II regulations by quantifying the fuel savings from vehicles with higher fuel economy. The results of the model show fleets the potential recovery in costs that could be expected with higher efficiency vehicles, although there is some uncertainty based on fuel price predictions and technology reliability. As shown in Figure 2-9 below, the calculation uses baseline, Phase I and Phase II fuel economy (FE) inputs along with annual mileage, then depending on fuel price and technology cost, outputs the fleet payback.

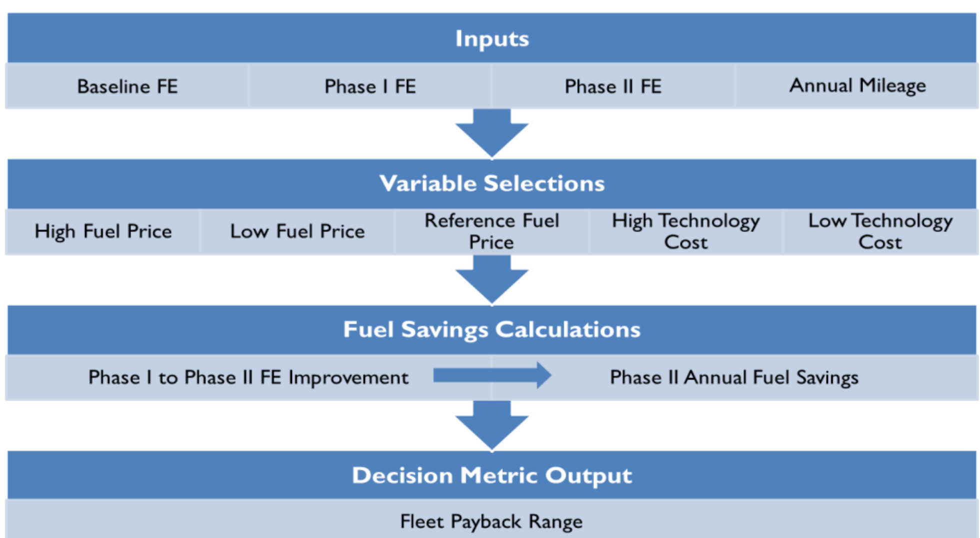


Figure 2-9: Fleet payback calculation input and process diagram

Future fuel prices were generated from the U.S. Energy Information Administration's *Annual Energy Outlook 2015*, which lists a high-oil, low-oil, and reference-oil price that affects diesel and gasoline prices a little differently. The predicted price for diesel in 2020, the first year of our Phase II payback analysis was $3.28, and the corresponding price of gasoline was $2.81. UCS vehicle cost data came from a comprehensive study produced in 2009 that allowed for changes in technology costs up to 2020. A low-cost was calculated as half the 2009 estimate and a high-cost was calculated by multiplying the 2009 estimate by one and a half. The fuel economy improvement percentage from Phase I to Phase II is then applied to the annual mileage, providing the fuel savings responsible for payback of the incremental technology cost.

3. FINDINGS

Using the Modified Life Cycle Cost (LCC) Model inputs shown in section 2.4, and appropriate technology groupings, CALSTART generated the associated fuel economy and fuel consumption reduction percentages for each vehicle category in the 2020 timeframe. These improvements are compared to an EPA Phase I-equipped vehicle and a 2010 baseline version, using fleet data on real-world efficiency for the baseline. Fleet payback on the incremental cost of these technologies is presented to illustrate the influence of vehicle use profile characteristics on the feasibility of technology adoption. Additionally, fleet reaction to these data analyses is presented to ground the discussion on payback and technology adoption.

3.1 Advanced Technology Packages and Fleet Payback Results

Each vehicle category presented in Section 2.3 has a different package of potential technology options that can provide the most opportunities for fuel displacement to meet the assumed fuel efficiency requirements. It is important that fleet vehicle specifications are taken into consideration when evaluating the different technology groups for each vehicle category and application, otherwise fuel savings may be negated by increased weight or other performance-depleting causes.

Technology applicability is presented by providing a range of fuel reduction percentages for a given technology area and then comparing the percentages to a 2010 baseline vehicle adapted from the UCS study.[5] Some of the technology areas are already being addressed through the Phase I rule and therefore do not factor into the Phase II calculations. In some cases, technology fuel consumption reductions were adjusted to reflect application-specific performance or known industry capabilities. Fuel savings in individual technology areas are not directly additive and therefore fuel consumption reduction totals for Phases I and II combined and Phase II alone are specifically listed. These totals are then converted to an average fuel economy for each step toward 2025, which are presented in this section.

Finally, the range in Phase II technology costs, adapted from the UCS study and Department of Energy SuperTruck proceedings, are listed to provide background for the payback calculation in each vehicle category.[6] As mentioned previously, the low-cost was calculated as half the 2009 estimate for appropriate technologies in each vehicle category and the high-cost was calculated by multiplying this 2009 estimate by one and a half.

3.1.1 Heavy-Duty Over-the-Road Trucks Results

With high annual mileage and low relative fuel economy, fleets operating heavy-duty over-the-road vehicles can greatly benefit from higher efficiency vehicles resultant of stronger fuel economy standards. Figure 3-1 below shows how heavy-duty over-the-road vehicles could benefit from significant improvements in all the technology areas to reach 10.0 MPG with this potential stemming from the Phase II standards modeled in this analysis.

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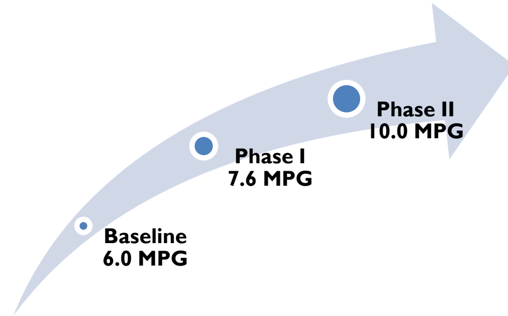
[5] Cooke, Dave, Khan, Siddiq, Tonachel, Luke. "Fuel Savings Available in New Heavy-Duty Trucks in 2025." *Union of Concerned Scientists*. Pub Nov 2014. (4/30/15).

[6] "DOE SuperTruck Program Benefits Analysis." *TA Engineering, Inc*. Pub Dec 2012. (2/9/15).

Heavy-Duty Over-the-Road	Fuel Consumption Reduction	
	Min.	Max.
Engine Optimization	8.7%	15.0%
Waste Heat Recovery	4.0%	6.0%
Transmission & Driveline	7.0%	7.0%
Hybridization	3.0%	5.0%
Improved Aerodynamics	11.0%	12.0%
Electrification of Accessories	2.0%	4.0%
Wheels & Tires	3.0%	6.0%
Weight Reduction	2.4%	2.4%
Totals (Phase I & II)	*34.7%*	*45.3%*
Totals (Phase II)	**18.2%**	**30.6%**



Phase II - Low Cost

- $14,000

Phase II - High Cost

- $42,000

Figure 3-1: Fuel consumption reduction and fuel economy improvement for the heavy-duty over-the-road vehicle category

Engine optimization and improvement aerodynamics are estimated to provide the most fuel consumption reduction for the heavy-duty over-the-road vehicle category. There are several technology packages that could contribute to achieving this efficiency. For purposes of the analysis, CALSTART used this package as its basis, covering the most applicable and likely technologies that would impact the heavy-duty over-the-road sector. The Phase II technology package cost is estimated to range from $14,000 to $42,000. The combined impact of both Phase I and Phase II standards has the potential to reduce fuel consumption by roughly 35 to 45 percent. Figure 3-2 below shows the payback period of a Phase II technology package capable of 24% fuel consumption reduction, the midpoint of the range listed in Figure 3-1.

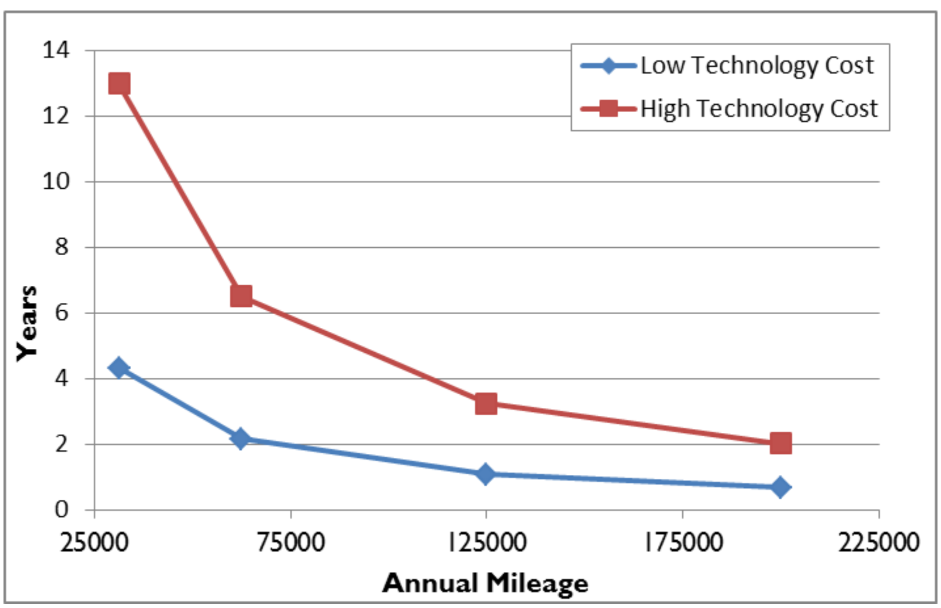


Figure 3-2: Payback curves for heavy-duty over-the-road vehicle category

At 125,000 annual miles, the average annual mileage for this vehicle category identified in the fleet interviews, Phase II technology payback is between one and three years.[7] A Class 8 fleet operator noted that, **"The (payback) chart looks about right; high mileage trucks reap the benefit a lot quicker, and low mileage trucks take longer, but we also keep those trucks longer."**

This is an important point, as fleets that would look immediately at the left half of the payback chart might be worried by the length of their technology payback, but in reality those lower-annual mileage vehicles will retain their value longer than the high-mileage ones. Therefore, fleets should be able to tolerate a longer payback on these lower annual mileage vehicles simply because they are keeping them longer and receiving a relatively consistent fuel reduction benefit. It is this continual fuel cost reduction that can also hold ancillary benefits, as a produce delivery fleet explained that **"Fuel economy improvement means a lot more than just the cost of fuel; you don't have to refuel as often, can spend more time moving product, and reduce administration cost behind paying fuel bills."**

"The (payback) chart looks about right; high mileage trucks reap the benefit a lot quicker, and low mileage trucks take longer, but we also keep those trucks longer."
–Class 8 Fleet Operator

Beyond monetary savings and payback, significant fuel and greenhouse gas (GHG) emission savings can be achieved with Phase II standards as shown in Figure 3-3.

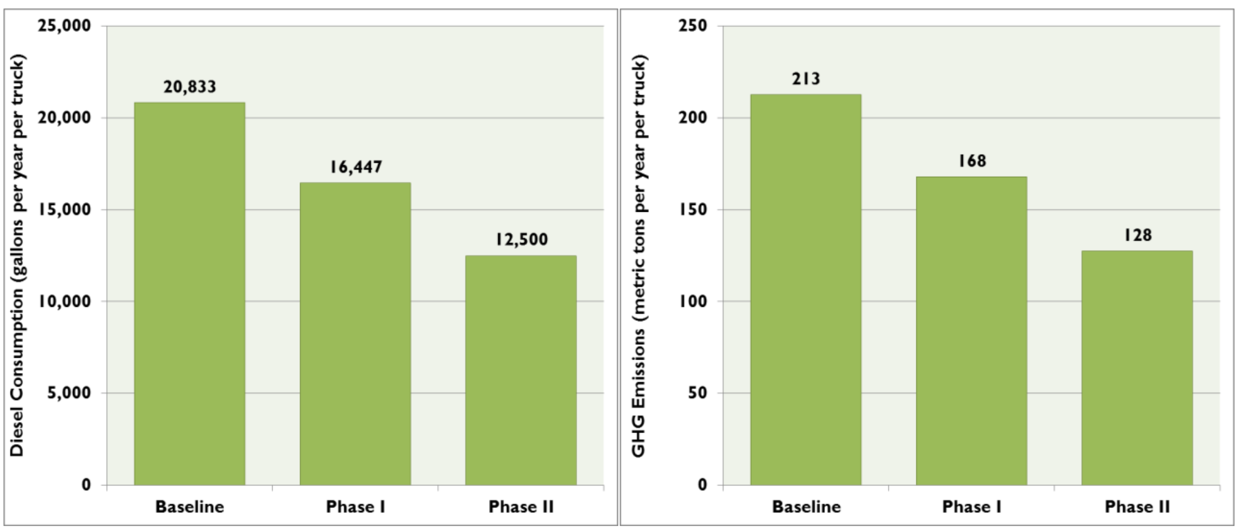


Figure 3-3: Baseline, Phase I, and Phase II fuel consumption and GHG emissions for heavy-duty over-the-road vehicles

Compared to a baseline heavy-duty over-the-road truck, a Phase II truck could reduce 8,300 gallons of diesel and 85 metric tons of GHG. Compared to a Phase I heavy-duty over-the-road truck, a Phase II truck could save 3,947 gallons of diesel and 40 metric tons of GHG. These savings are contingent upon reliable vehicle performance.

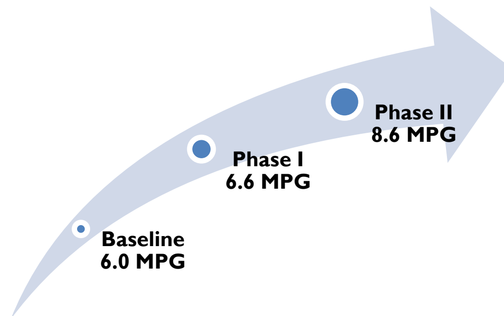
[7] Payback is based on annual fuel savings calculations, which are highly influenced by the price of oil. For this calculation the EIA AEO2015 Reference price for diesel of $3.28 per gallon was used.

If there is concern in this segment as well as others, it is that fleets want to make sure they get good operational and performance data on the solutions OEMs bring forward in advance. The long lead time of the new proposed rule should allow this to happen.

3.1.2 Heavy-Duty Short-Haul/Regional Results

With relatively high mileage and low fuel economy, fleets operating heavy-duty short-haul/regional vehicles can also benefit from stronger fuel economy standards. Figure 3-4 shows how heavy-duty short-haul/regional vehicles could benefit from improvements in nearly all the technology areas to reach 8.6 MPG with Phase II standards.

Heavy-Duty Short-Haul / Regional	Fuel Consumption Reduction	
	Min.	Max.
Engine Optimization	8.7%	15.0%
Waste Heat Recovery	-	-
Transmission & Driveline	7.0%	7.0%
Hybridization	-	-
Improved Aerodynamics	5.5%	5.5%
Electrification of Accessories	2.0%	4.0%
Wheels & Tires	3.0%	6.0%
Weight Reduction	2.4%	2.4%
Totals (Phase I & II)	*25.6%*	*34.2%*
Totals (Phase II)	**18.3%**	**27.0%**



Phase II - Low Cost
- $4,500

Phase II - High Cost
- $13,500

Figure 3-4: Fuel consumption reduction and fuel economy improvement for the heavy-duty short-haul/regional vehicle category

Engine optimization, transmission and driveline improvements are estimated to provide the most fuel displacement benefits for the heavy-duty short-haul/regional vehicle category. The Phase II technology package cost is estimated to range from $4,500 to $13,500. The combined impact of both Phase I and Phase II standards has the potential to reduce fuel consumption by approximately 25 to 34 percent. Figure 3-5 below shows the payback period of a Phase II technology package capable of 23% fuel consumption reduction, roughly the midpoint of the range listed in Figure 3-4.

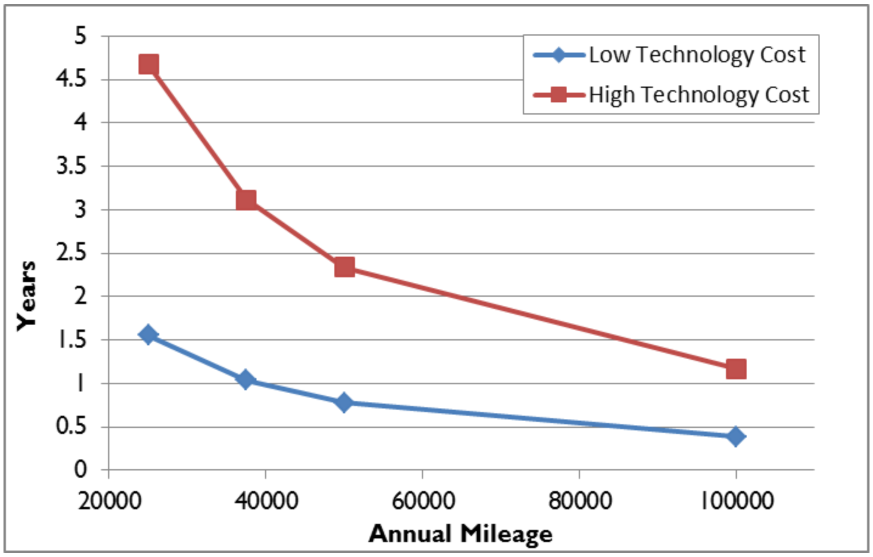


Figure 3-5: Payback curves for heavy-duty short-haul/regional vehicle category

At 68,000 annual miles, the average annual mileage for this vehicle category identified in the fleet interviews, Phase II technology payback is between seven months and two years.[8] Payback is highly dependent on annual mileage, as increasing mileage increases total fuel savings compared to a baseline vehicle. In reference to adopting advanced technology with a longer-term payback, a regional operator explained that **"Half a mile per gallon improvement is six thousand dollars a year to us; it is worth it to spend it now because I know I'll get it back in a year or two and then keep reaping the benefit."**

This is particularly appropriate when reviewing the technology package in Figure 3-4, which highlights many technology areas that may result in modest fuel savings at relatively low cost in comparison to the conventional vehicle itself. As one fleet operator put it, **"Engine (and transmission) optimization is pushing fuel economy; taller gearing enables highway driving at a lower gear, which runs the vehicle at much lower rpm."** This relatively simple strategy (though admittedly more complicated to enact) could have major benefit for heavy-duty vehicles running both over-the-road and regional-haul routes. Beyond any monetary savings and payback, significant fuel and greenhouse gas (GHG) emission savings can be achieved with Phase II standards as shown in Figure 3-6.

"Half a mile per gallon improvement is six thousand dollars a year to us; it is worth it to spend it now because I know I'll get it back in a year or two and then keep reaping the benefit."

–Regional Truck Operator

[8] Payback is based on annual fuel savings calculations, which are highly influenced by the price of oil. For this calculation the EIA AEO2015 Reference price for diesel of $3.28 per gallon was used.

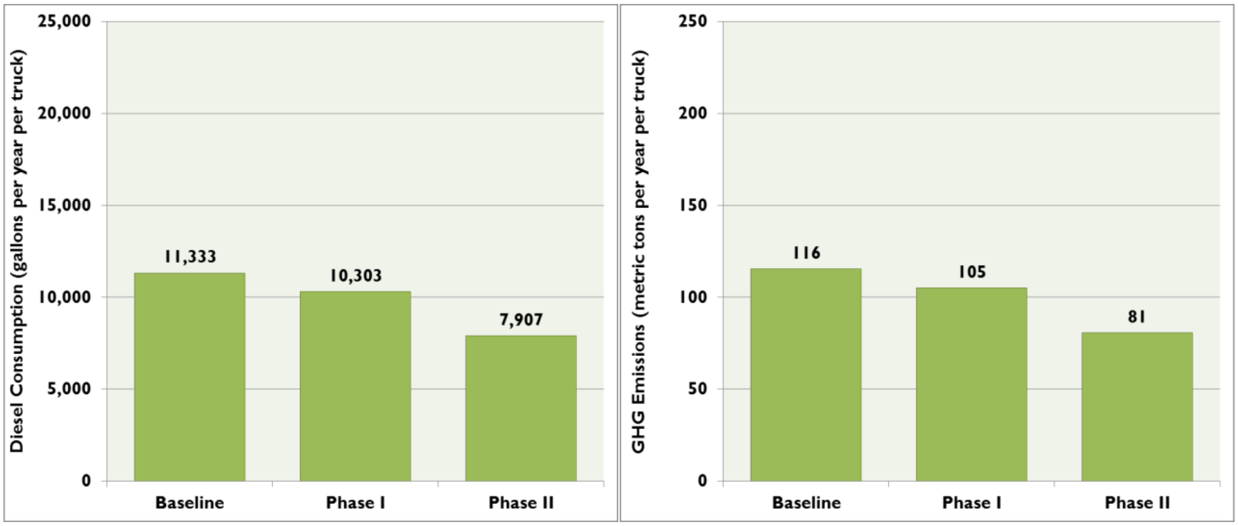


Figure 3-6: Baseline, Phase I, and Phase II fuel consumption and GHG emissions for heavy duty short-haul/regional vehicles

Compared to a baseline heavy-duty short-haul/regional truck, a Phase II truck could reduce 3,426 gallons of diesel and 35 metric tons of GHG. Compared to a Phase I heavy-duty short-haul/regional truck, a Phase II truck could save 2,396 gallons of diesel and 24 metric tons of GHG.

In achieving these results a produce fleet operator indicated the kind of support they need to see from manufacturers as they begin the technology roll-out. **"Buyers want to see hard data showing they (OEMs) ran the trucks for a long time; I get great fuel economy data but (they) didn't show reliability data."** Clearly, this reliability information would go a long way to assuaging fears about adopting new technology and how to minimize impact on operations.

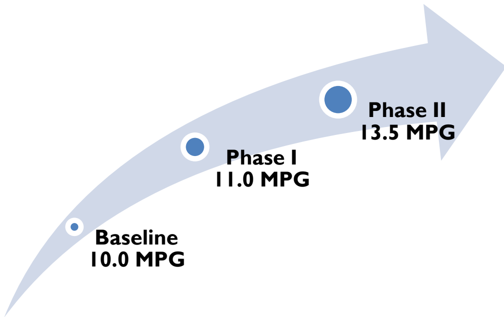
3.1.3 Medium-Duty Rural/Intra-city Results

With median annual mileage and higher fuel economy than other vehicle categories, fleets operating medium-duty rural/intra-city vehicles can benefit from stronger fuel economy standards. Figure 3-7 below shows how medium-duty rural/intra-city vehicles could achieve fuel reduction benefits by reaching 13.5 MPG with Phase II standards.

"We try to make 96 month decisions, not six month decisions; we want to get benefits for the next eight years."

–National Fleet Operator

Medium-Duty Rural / Intra-city	Fuel Consumption Reduction Min.	Fuel Consumption Reduction Max.
Engine Optimization	4.9%	9.6%
Waste Heat Recovery	-	-
Transmission & Driveline	8.0%	10.0%
Hybridization	-	-
Improved Aerodynamics	5.0%	8.0%
Electrification of Accessories	2.0%	4.0%
Wheels & Tires	2.0%	4.0%
Weight Reduction	-	-
Totals (Phase I & II)	*20.2%*	*31.0%*
Totals (Phase II)	**14.3%**	**21.9%**



Phase II - Low Cost

- $1,500

Phase II - High Cost

- $4,500

Figure 3-7: Fuel consumption reduction and fuel economy improvement for the medium-duty rural/ intra-city vehicle category

Engine optimization, transmission and driveline, and aerodynamic improvements provide the most benefits in the reduction of fuel for the medium-duty rural/intra-city vehicle category. The Phase II technology package cost is estimated to range from $1,500 to $4,500. The combined impact of both Phase I and Phase II standards has the potential to reduce fuel consumption by roughly 20 to 31 percent. Figure 3-8 below shows the payback period of a Phase II technology package capable of 18% fuel consumption reduction, the approximate midpoint of the range listed in Figure 3-7.

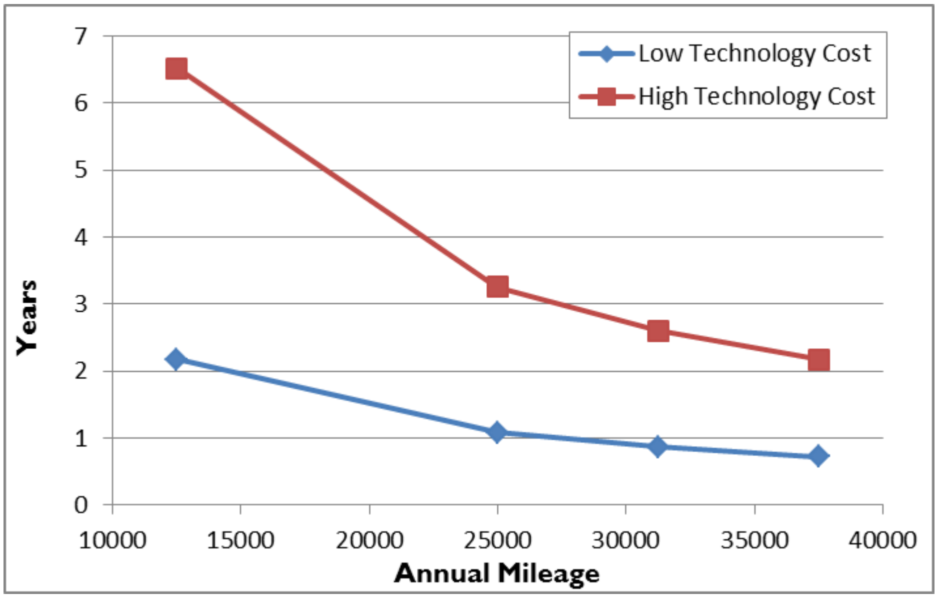


Figure 3-8: Payback curves for medium-duty rural/intra-city vehicle category

At 37,500 annual miles, the average annual mileage for this vehicle category identified in the fleet interviews, Phase II technology payback is between eight months and two years.[9] Payback is highly dependent on annual mileage, as increasing mileage increases total fuel savings compared to a baseline vehicle. A large national fleet operator explained how the longer payback at lower mileage in the curve above is not an automatic deal-breaker for vehicle acquisitions. ***"We try to make 96 month decisions, not six month decisions; we want to get benefits for the next eight years."***

In accomplishing this long-term strategy, fleets are relying on increasingly advanced models that look at route-specific details to determine appropriate vehicle assignment. In many cases, annual mileage alone cannot provide the appropriate metric with which to align fuel consumption or potential savings. Beyond these monetary savings and technology payback, significant fuel and greenhouse gas (GHG) emission savings can be achieved with Phase II standards as shown in Figure 3-9.

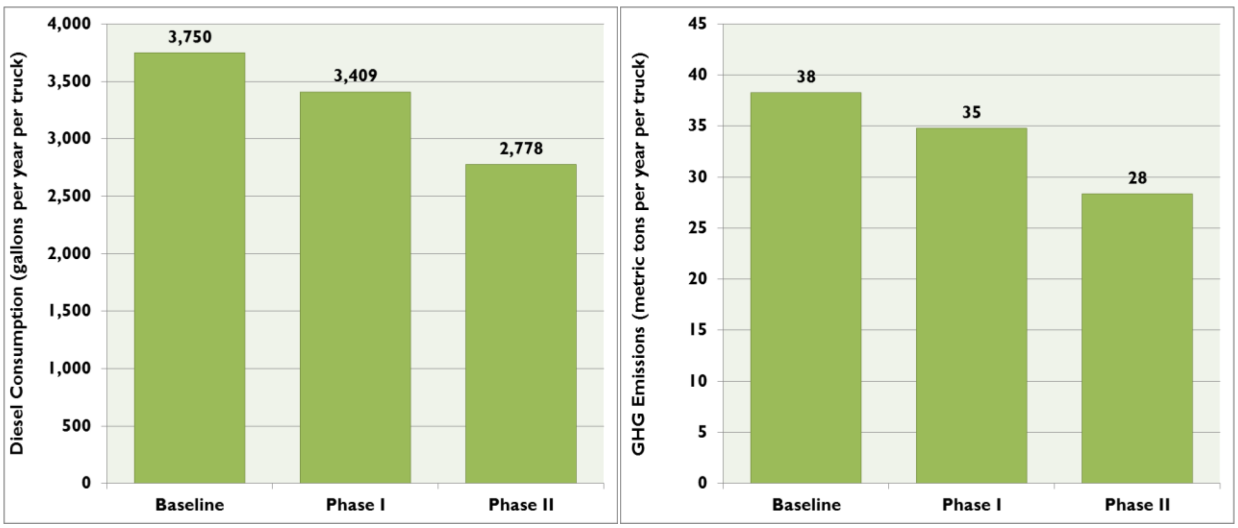


Figure 3-9: Baseline, Phase I, and Phase II fuel consumption and GHG emissions for medium duty rural/intra-city vehicles

Compared to a baseline medium-duty rural/intra-city truck, a Phase II truck could reduce 972 gallons of diesel and ten metric tons of GHG. Compared to a Phase I medium-duty rural/intra-city truck, a Phase II truck could save 631 gallons of diesel and seven metric tons of GHG. The modest savings and technology package cost detailed in Figure 3-7 is indicative of the medium duty sector today.

There are many opportunities for cost reduction both in new technologies and vehicle right-sizing to specific applications, with the effectiveness of solutions highly dependent on the quality of operational and performance data collected. One delivery vehicle operator said that ***"we look at everything today; the organization is (really) starting to get down to sustainability,"*** an explanation that represents what was once the leading edge of fleet operations but is swiftly becoming the norm.

3.1.1 Medium-Duty Urban Results

With lower annual mileage and fuel economy than the previous medium duty category, fleets operating medium-duty urban vehicles can benefit even more from stronger fuel economy standards. Figure 3-10

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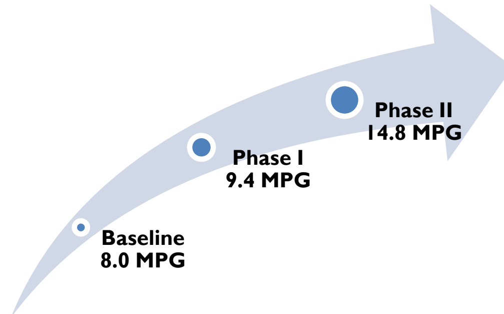
[9] Payback is based on annual fuel savings calculations, which are highly influenced by the price of oil. For this calculation the EIA AEO2015 Reference price for diesel of $3.28 per gallon was used.

below shows how medium-duty urban vehicles could benefit from improvements in some technology areas to reach 14.8 MPG with Phase II standards.

Medium-Duty Urban	Fuel Consumption Reduction	
	Min.	Max.
Engine Optimization	4.9%	9.6%
Waste Heat Recovery	-	-
Transmission & Driveline	8.0%	10.0%
Hybridization	20.0%	40.0%
Improved Aerodynamics	2.0%	4.0%
Electrification of Accessories	2.0%	4.0%
Wheels & Tires	1.0%	2.0%
Weight Reduction	-	-
Totals (Phase I & II)	*33.5%*	*55.9%*
Totals (Phase II)	**21.4%**	**47.9%**



Phase II - Low Cost

- $10,000

Phase II - High Cost

- $30,000

Figure 3-10: Fuel consumption reduction and fuel economy improvement for the medium-duty urban vehicle category

Hybridization, transmission and driveline improvements provide the most benefits in fuel consumption reduction for the medium-duty urban vehicle category. The Phase II technology package cost is estimated to range from $10,000 to $30,000. The combined impact of both Phase I and Phase II standards has the potential to reduce fuel consumption by approximately 34 to 56 percent. Figure 3-11 below shows the payback period of a Phase II technology package capable of 36% fuel consumption reduction, just above the midpoint of the range listed in Figure 3-10.

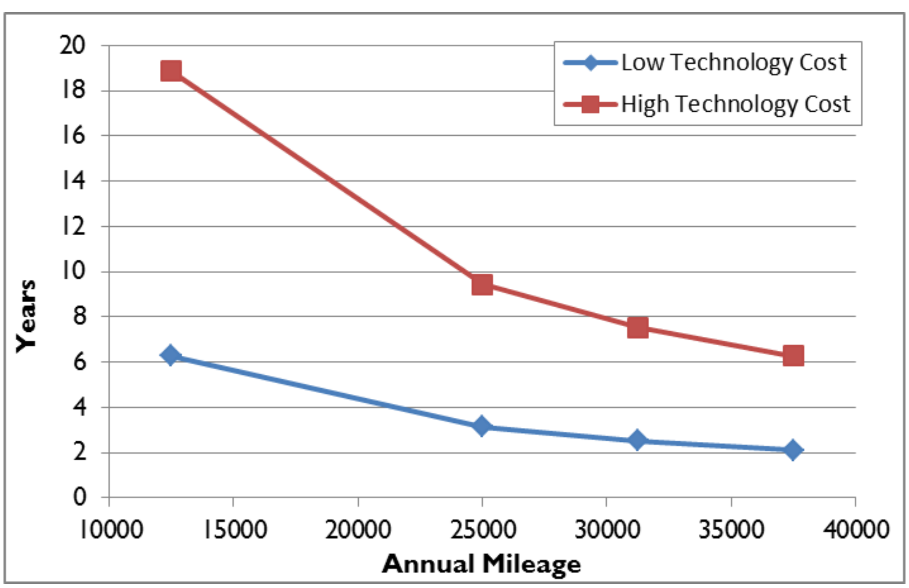


Figure 3-11: Payback curves for medium-duty urban vehicle category

At 18,750 annual miles, the average annual mileage for this vehicle category identified in the fleet interviews, Phase II technology payback is between four and 13 years.[10] These vehicles may be kept upwards of ten years, so longer payback is more tolerable than in other vehicle sectors. Additionally, the performance of individual vehicles holds weight, a national services fleet operator mentioned that, **"(In our business, fuel economy is important); we use modeling that shows the expected fuel savings and the expected carbon footprint."**

Fleets are accepting of the general case that future technology can show them a payback, but as the dates of deployment get close, they also do want to see the data on the actual technology being used on the future trucks so they can build a full life cycle model. The emissions data can be a significant driver for vehicle acquisition and route assignment for a variety of fleets, fuel and greenhouse gas (GHG) emission savings can be achieved with Phase II standards as shown in Figure 3-12.

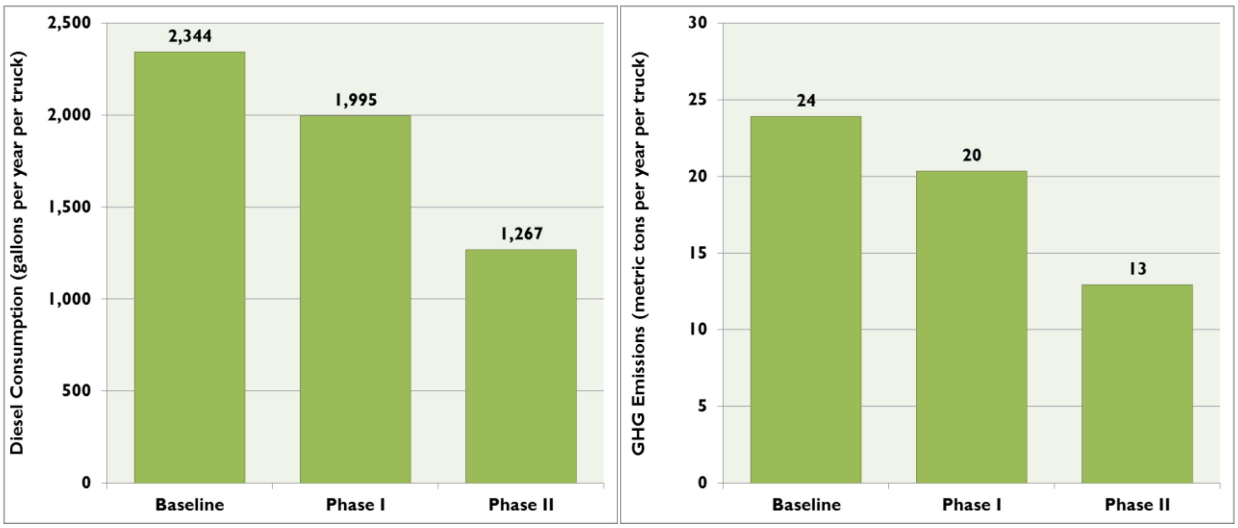


Figure 3-12: Baseline, Phase I, and Phase II fuel consumption and GHG emissions for medium duty urban vehicles

Compared to a baseline medium-duty urban truck, a Phase II truck could reduce 1,077 gallons of diesel and 11 metric tons of GHG. Compared to a Phase I medium-duty urban truck, a Phase II truck could save 728 gallons of diesel and seven metric tons of GHG.

3.1.2 Medium-Duty Work Site Support Results

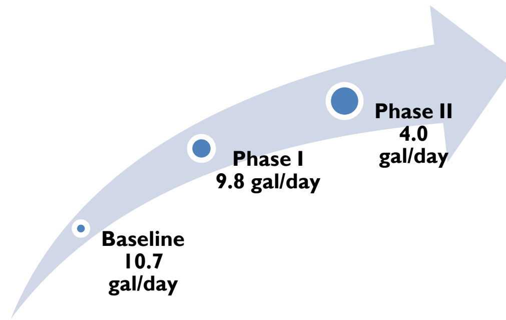
Work site support duty cycles tend to be highly variable. For instance, on one day, a work site support vehicle could make a short trip to a work site, requiring multiple hours of engine idling. The next day, the vehicle could be assigned to multiple emergency repairs with considerable distance between each repair. In order to characterize this variability, the fuel savings model from a known supplier of hybrid drivetrains was adapted to provide the daily fuel consumption estimates for a Phase II-equipped vehicle.

With relatively low annual mileage but high baseline daily fuel consumption, fleets operating medium-duty work site support vehicles can still benefit from stronger fuel economy standards. Figure 3-13

[10] Payback is based on annual fuel savings calculations, which are highly influenced by the price of oil. For this calculation the EIA AEO2015 Reference price for diesel of $3.28 per gallon was used.

below shows how medium-duty urban vehicles could benefit from improvements in some technology areas to reach 4.0 gallons per day with Phase II standards.

Medium-Duty Work Site Support	Fuel Consumption Reduction	
	Min.	Max.
Engine Optimization	4.9%	9.6%
Waste Heat Recovery	-	-
Transmission & Driveline	8.0%	10.0%
Hybridization	40%	52%
Improved Aerodynamics	1.0%	2.0%
Electrification of Accessories	-	-
Wheels & Tires	1.0%	2.0%
Weight Reduction	-	-
Totals (Phase I & II)	*48.5%*	*62.6%*
Totals (Phase II)	*45.3%*	*59.2%*



Phase II - Low Cost
- $25,000

Phase II - High Cost
- $35,000

Figure 3-13: Fuel consumption reduction and associated cost range for the medium-duty work site support vehicle category

Hybridization, transmission and driveline improvements provide the most fuel displacement for the medium-duty work site support vehicle category. The Phase II technology package cost is estimated to range from $25,000 to $35,000. The combined impact of both Phase I and Phase II standards has the potential to reduce fuel consumption by roughly 49 to 63 percent.

This vehicle category includes numerous duty cycles and results will be highly contingent upon appropriate use of idle reduction technologies and proper hybrid driving techniques. The daily fuel consumption values shown above were adapted from one such duty cycle, details are shown in Table 3-1.

Table 3-1: Work site support vehicle duty cycle and fuel consumption

Duty Cycle Portion	Baseline Fuel Consumption (gal)	Phase I Fuel Consumption (gal)	Phase II Fuel Consumption (gal)
Driving (32 miles/day)	5.26	4.31	4.01
ePTO at job site (4.2 hours/day)	4.02	4.02	0.00
Hydraulic Load (1.0 hours/day)	1.47	1.47	0.00
Work Day Total	10.74	9.80	4.01

Phase I technologies will only address the driving portion of the duty cycle, with an advanced hybrid transmission capable of saving fuel via regenerative braking and other engine efficiencies. The main difference between electric power take-off (ePTO) and hydraulic loads are the energy requirement, approximately 1 gallon and 1.5 gallons of diesel per hour are needed, respectively, to support these different operations. In this particular drive cycle, these loads require more fuel than the actual drive-time, therefore major fuel savings occur with Phase II-equipped vehicles that are capable of significant no-idle activities, covering all the ePTO, export power, and hydraulic loads. Figure 3-14 below shows the payback period of this particular Phase II technology package, capable of 59% fuel consumption reduction, the maximum listed in Figure 3-13.

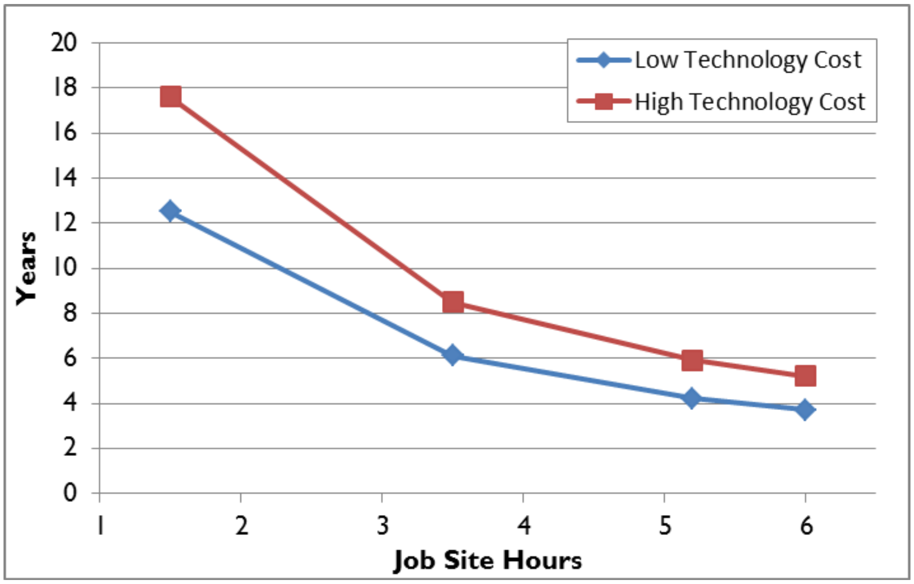


Figure 3-14: Payback curves for medium-duty work site support vehicle category

In the example duty cycle shown in Table 3-1 with a total of 5.2 job site hours, payback on the Phase II technology package is between four and six years.[11] Payback is highly dependent on daily hours at the job site, as increasing engine-off operations increases total fuel savings compared to a baseline vehicle. There are additional monetary benefits to increased engine-off operations, as one regional utility fleet put it, **"increasing no-idle time lets us run the engine less, which saves fuel, saves on maintenance costs, and extends the vehicle lifetime."** Since engine hours directly impact wear and tear on engine and emission systems components, no-idle hours can drastically impact both annual and lifecycle maintenance costs. While reviewing the figures above, one fleet even suggested that, depending on the amount of engine-on time reduced, their replacement protocol could increase from six to eight years while increasing the resale value of the vehicles due to the improved condition of individual components.

"Increasing no-idle time lets us run the engine less, which saves fuel, saves on maintenance costs, and extends the vehicle lifetime."

–Regional Utility Fleet Manager

For this particular case, engine hours are better signals of fuel use than annual mileage, though idling can vary widely by day and application. This must play into how fleets manager their acquisitions. A large fleet with significant urban operations noted that, **"when building a sustainable fleet program, we are looking at hours of operation versus mileage; a utility fleet (for example) has to look at engine hours to try to make sense of fuel consumption."**

[11] Payback is based on annual fuel savings calculations, which are highly influenced by the price of oil. For this calculation the EIA AEO2015 Reference price for diesel of $3.28 per gallon was used.

Current regulatory rule structures do not easily give credit to such solutions from a compliance standpoint, and the technologies are currently expensive. One Midwestern utility fleet noted that, **"the payback presented here looks like something we could support and something that would be helpful to us, but (with the after-treatment legislation) we felt like we were left out and couldn't adjust to the new technology based on the information being provided."**

To help avoid the costs associated with new technology roll-out, fleets indicated a strong need for maintenance data from the OEMs specific to their application, such as component replacement information based on total engine-hours rather than cumulative mileage.

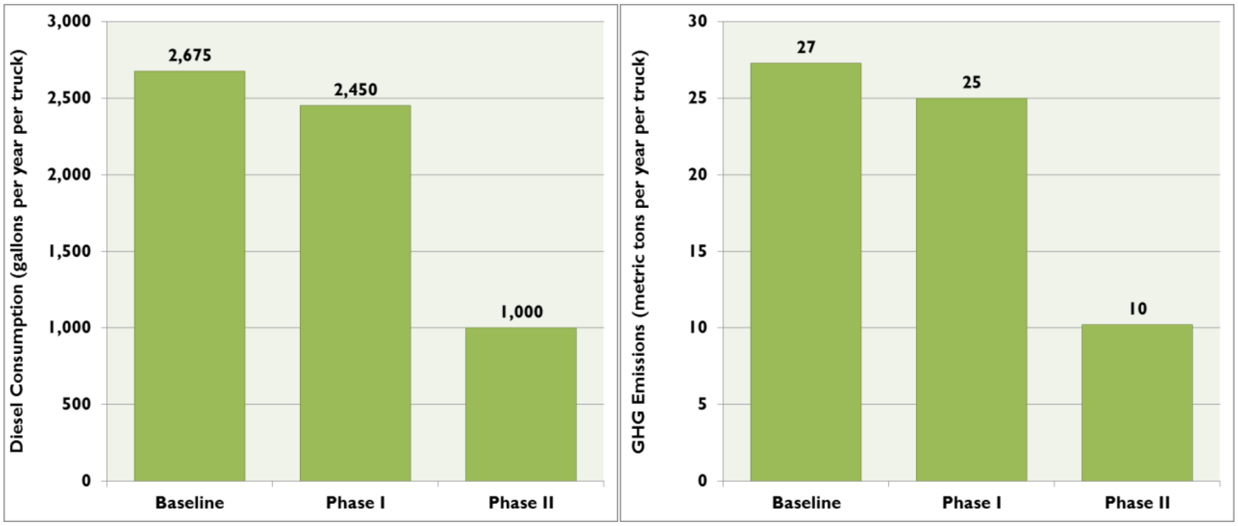


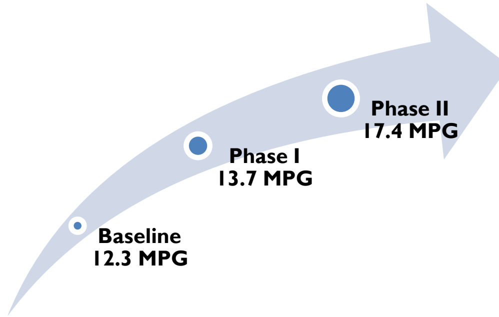
Figure 3-15: Baseline, Phase I, and Phase II fuel consumption and GHG emissions for medium-duty work site support vehicles

A breakdown of the fuel and GHG emission savings expected is shown in Figure 3-15.

3.1.3 Class 2B Gasoline Truck and Van Results

With similar annual mileage to medium-duty vehicles but higher baseline fuel economy, fleets operating Class 2b gasoline vehicles can benefit from stronger fuel economy standards, approaching the fuel economy of some passenger vehicles. Figure 3-16 shows medium-duty urban vehicle potential.

Class 2B Trucks & Vans Gasoline	Fuel Consumption Reduction Min.	Fuel Consumption Reduction Max.
Engine Optimization	9.7%	15.1%
Waste Heat Recovery	-	-
Transmission & Driveline	7.5%	7.5%
Hybridization	4.0%	4.0%
Improved Aerodynamics	3.0%	3.0%
Electrification of Accessories	2.0%	4.0%
Wheels & Tires	2.0%	2.0%
Weight Reduction	1.6%	1.6%
Totals (Phase I & II)	*26.5%*	*32.3%*
Totals (Phase II)	**18.1%**	**24.6%**



Phase II - Low Cost
- $2,000

Phase II - High Cost
- $6,000

Figure 3-16: Fuel consumption reduction and fuel economy improvement for the class 2B gasoline truck and van vehicle category

Engine optimization, transmission and driveline improvements are estimated to provide the most benefits with fuel displacement for the class 2B gasoline truck and van vehicle category. The Phase II technology package cost is estimated to range from $2,000 to $6,000. The combined impact of both Phase I and Phase II standards has the potential to reduce fuel consumption by 27 to 32 percent. Figure 3-17 shows the payback period of a Phase II technology package capable of 21% fuel consumption reduction, the midpoint of the range listed in Figure 3-16.

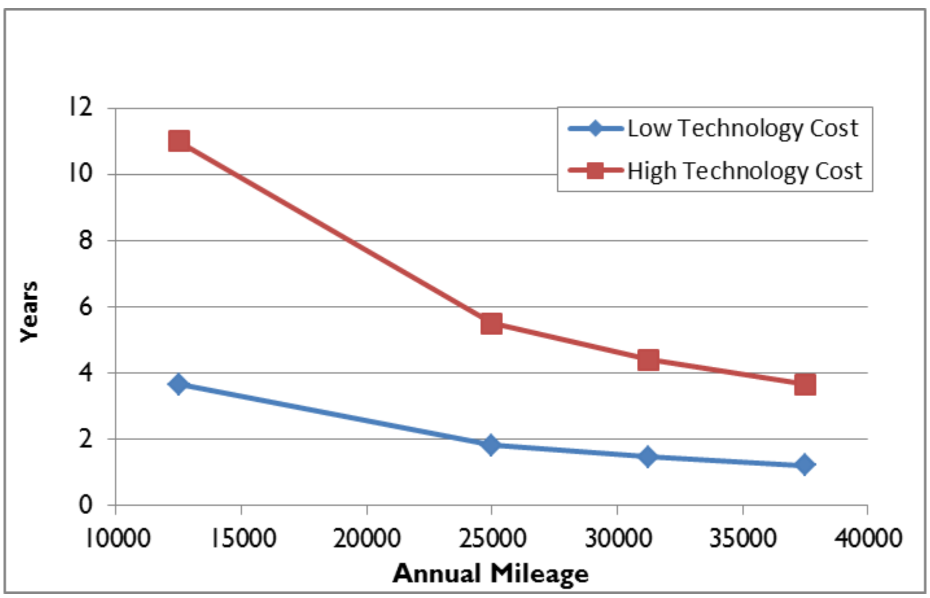


Figure 3-17: Payback curves class 2B gasoline trucks and vans

At 25,000 annual miles, the average annual mileage for this vehicle category identified in the fleet interviews, Phase II technology payback is between two and six years.[12] One of the main

[12] Payback is based on annual fuel savings calculations, which are highly influenced by the price of oil. For this calculation the EIA AEO2015 Reference price for diesel of $3.28 per gallon was used.

disappointments for fleets operating in this sector is the lack of technology transfer and scaling from light-duty. A large fleet operated mentioned that, **"hybridization is popular in the light-duty market but not at the heavy-duty OEM level. I'm surprised because the technology should apply to pickups and vans; if it were more widely applied then the incremental cost might be reduced."**

This sentiment is impactful, particularly due to the range in payback between the low and high-cost curves shown in the figure above. If incremental cost of, for example, hybridization could be reduced, this gap would narrow, possibly spurring technology adoption in this sector. Beyond monetary savings and payback, significant fuel and greenhouse gas (GHG) emission savings can be achieved with Phase II standards as shown in Figure 3-18.

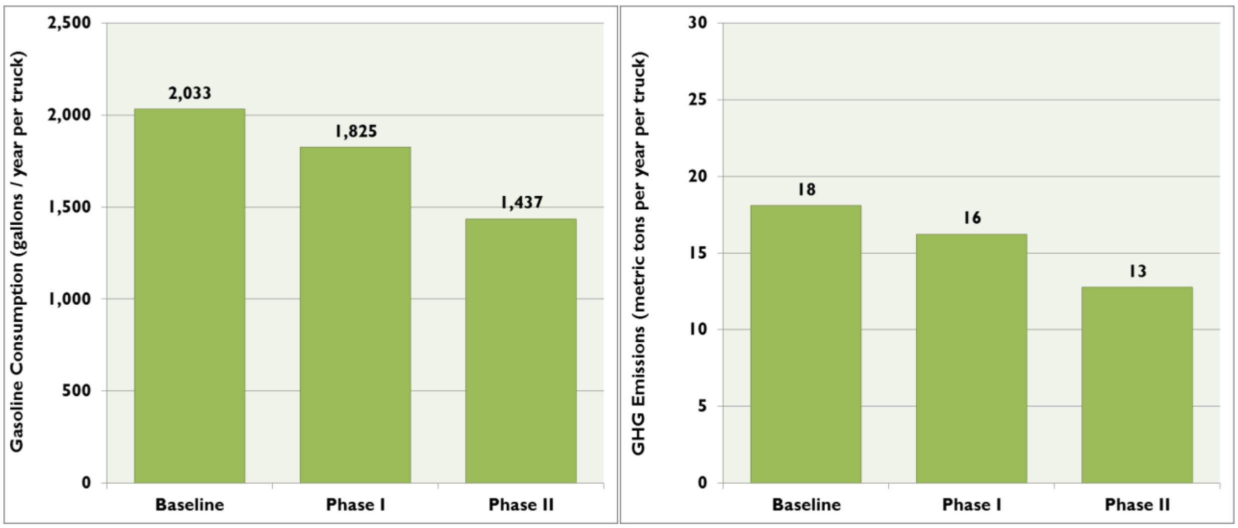


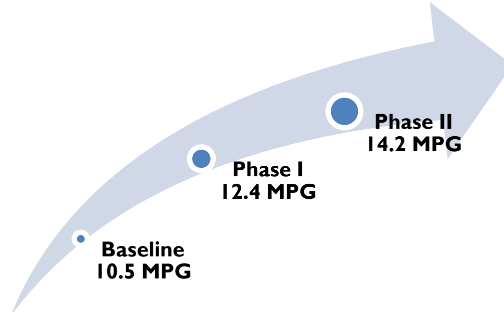
Figure 3-18: Baseline, Phase I, and Phase II fuel consumption and GHG emissions for class 2b gasoline trucks and vans

Compared to a baseline Class 2B gasoline vehicle, a Phase II truck or van could reduce 596 gallons of gasoline and five metric tons of GHG. Compared to a Phase I class 2B gasoline vehicle, a Phase II truck or van could save 388 gallons of gasoline and three metric tons of GHG.

3.1.4 Class 2B Diesel Truck and Van Results

With identical annual mileage to Class 2B gasoline vehicles but lower real-world baseline fuel economy (likely due to different operational and duty cycle uses), fleets operating Class 2B diesel vehicles can benefit from stronger fuel economy standards, approaching the fuel economy of some medium-duty trucks. Figure 3-19 below shows how medium-duty urban vehicles could benefit from improvements in most technology areas to reach 14.2 MPG with Phase II standards.

Class 2B Trucks & Vans Diesel	Fuel Consumption Reduction	
	Min.	Max.
Engine Optimization	7.3%	13.3%
Waste Heat Recovery	-	-
Transmission & Driveline	7.5%	7.5%
Hybridization	2.0%	2.0%
Improved Aerodynamics	3.0%	3.0%
Electrification of Accessories	2.0%	4.0%
Wheels & Tires	2.0%	2.0%
Weight Reduction	1.6%	1.6%
Totals (Phase I & II)	*23.0%*	*29.4%*
Totals (Phase II)	**9.1%**	**16.7%**



Phase II - Low Cost
- $1,250

Phase II - High Cost
- $3,750

Figure 3-19: Fuel consumption reduction and fuel economy improvement for the class 2B diesel truck and van vehicle category

Engine optimization, transmission and driveline improvements are planned to provide the most fuel consumption reduction for the class 2B diesel truck and van vehicle category. The Phase II technology package cost is estimated to range from $1,250 to $3,750. The combined reduction benefits of both Phase I and Phase II standards have the potential to reduce fuel consumption by roughly 23 to 29 percent. Figure 3-20 below shows the payback period of a Phase II technology package capable of 13% fuel consumption reduction, the approximate midpoint of the range listed in Figure 3-19.

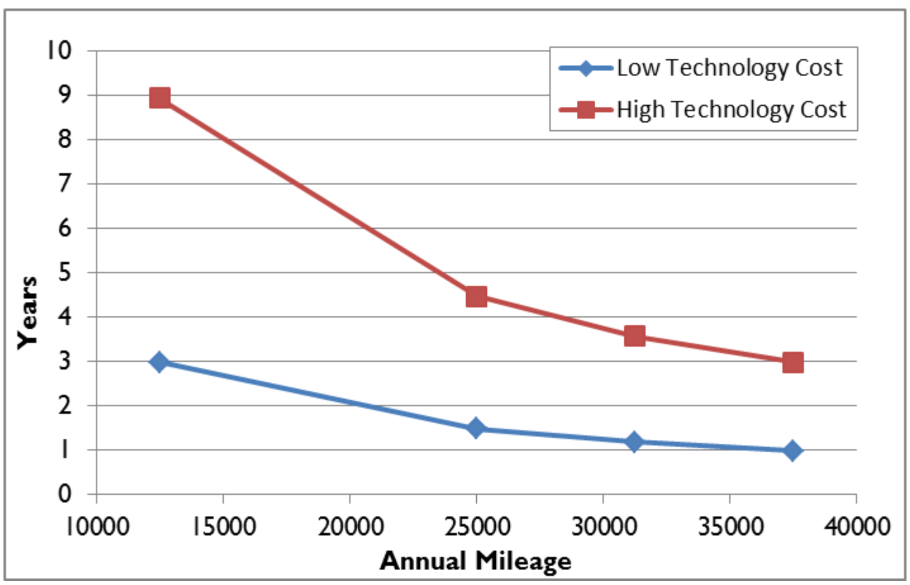


Figure 3-20: Payback curves for class 2b diesel trucks and vans

At 25,000 annual miles, the average annual mileage for this vehicle category identified in the fleet interviews, Phase II technology payback is between 1.5 and 4.5 years.[13] Similar to the gasoline trucks and

[13] Payback is based on annual fuel savings calculations, which are highly influenced by the price of oil. For this calculation the EIA AEO2015 Reference price for diesel of $3.28 per gallon was used.

vans of the previous section, fleets operating diesel variants were disappointed in the availability of advanced technologies in this sector that have become commonplace in light-duty vehicles. A national operator of vans and pickups said that, **"There is not enough start-stop technology (on these vehicles); it should be more widely deployed."**

Start-stop is a technology which reduces engine idle time, a particularly attractive benefit for vehicles like diesel trucks and vans which may be operating in more urban environments than gasoline variants. An additional bonus in this sector is the requirement for increasing accessory electrification with start-stop deployment, which in turn increases system and efficiency and paves the way for further transmission enhancements. Beyond the monetary savings and payback from these technologies, significant fuel and greenhouse gas (GHG) emission savings can be achieved with Phase II standards as shown in Figure 3-21.

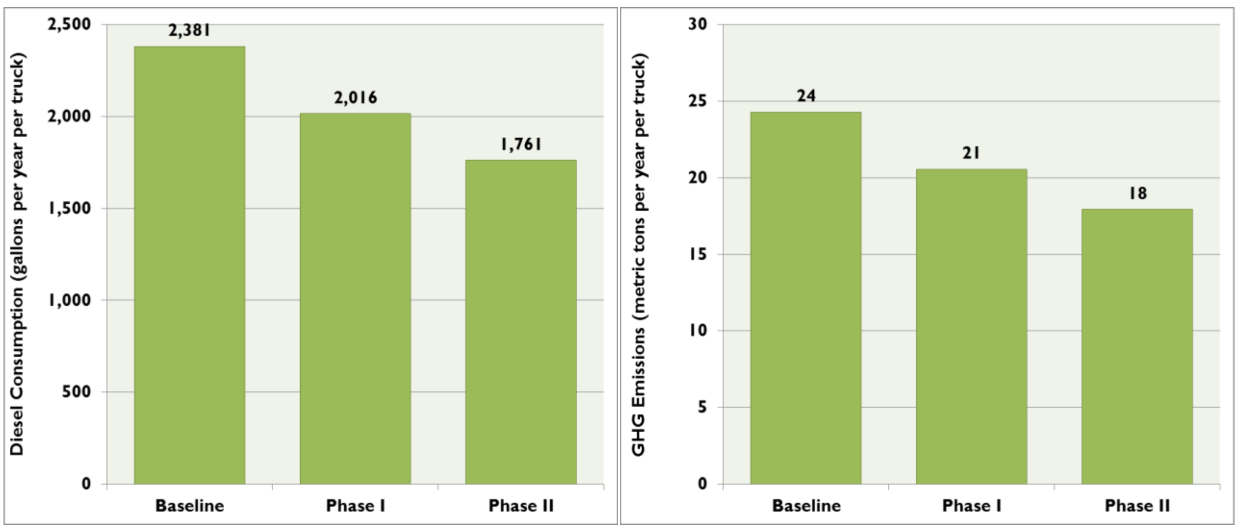


Figure 3-21: Baseline, Phase I, and Phase II fuel consumption and GHG emissions for class 2B diesel trucks and vans

Compared to a baseline Class 2B gasoline vehicle, a Phase II truck or van could reduce 620 gallons of diesel and six metric tons of GHG. Compared to a Phase I Class 2B gasoline vehicle, a Phase II truck or van could save 255 gallons of diesel and three metric tons of GHG.

> *"There is not enough start-stop technology (on these vehicles); it should be more widely deployed." –National Fleet Operating Vans and Pickups*

4. RECOMMENDATIONS

There are a number of recommendations for fleets to consider as EPA-NHTSA Phase II Fuel Economy standards are implemented. These stem from both the survey responses and one-on-one interviews with fleet managers that helped validate the Modified Life Cycle Cost (LCC) Model.

4.1 Assign New Vehicles Based on Specific Application

Fleets need to plan ahead on how new vehicles are best assigned to fleet operations. As shown in the previous section, technology payback can be highly dependent on either annual mileage or engine hours, depending on the application. Therefore, in order to have optimal payback, new technology should first be deployed in the highest fuel use applications, allowing for maximum savings. As newer technology becomes available and affordable for the highest fuel use applications, the original asset can be moved to a lower fuel use application where it will continue to achieve fuel savings, though at a lower rate. This fits the traditional regulation pattern requiring step-wise fuel economy improvements, meaning that savvy fleets with good information on their distinct routes and applications will be able to deploy vehicles in successive technology waves effectively.

4.2 Collect Baseline Use Data

In order for fleets to realize the greatest benefits from their advanced technology investments, they should follow some of the principles laid out in the NAFA Sustainable Fleet program, one of which is to use telematics to quantify vehicle and fuel usage on a per-asset or per-class basis[14]. GPS traces of different vehicle routes will also help determine ideal applications in which to deploy advanced technologies. As one fleet manager commented, **"there are different operations that use fuel differently, yard hostlers burn a lot of fuel with low mileage and could therefore benefit from idle reduction technologies."** Obtaining real-world results of engine hours and fuel consumed are key. As shown in the Findings section (section 3), high-idling vehicles (such as work-site support) are uniquely tied to these metrics more than annual mileage.

4.3 Provide Fleets with Application-Specific Reliability Data

As mentioned by multiple fleets from different vocations, component replacement and reliability data from the manufacturers that can be applied to their application would go a long way to informing purchase decisions and business plans. Avoiding the costs and headaches associated with the after-treatment system replacements and reliability issues is only feasible if fleets have useful preventive maintenance models. Appropriate data for specific applications, based on engine-hours for many utility fleets for example, would enable smarter procurement and less vehicle downtime.

4.4 Provide Deeper Analysis of Potential Maintenance Impacts

A common and repeated concern of fleets involved in or contacted for this report was around the issue of potentially higher maintenance costs for future technology. This was driven in part by observations of increased maintenance costs seen in the early years of advanced emission control systems deployment. Fleets want to better understand how maintenance costs may impact their business case, as it is an important component of a Life Cycle Cost model. The regulatory agencies are encouraged to assess the

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14 NAFA Sustainable Fleet Homepage: http://www.nafasustainable.org/

sensitivity of future payback to higher or lower maintenance cost assumptions. CALSTART may attempt an update to this report adding that sensitivity analysis element.

4.5 Use a Modified LCC and Payback Metrics

In order to make informed purchase decisions, fleets should consider using a Modified Life Cycle Cost (LCC) Model and incorporate real-world estimates along with upfront technology cost and known replacement data. In preliminary calculations where payback appears incompatible with business requirements, fleets should use more advanced metrics, incorporating elements like those shown in Figure 2-1 to determine whether an advanced technology vehicle might be less expensive to own over its lifetime than its conventional counterpart. The goal is to leverage the large percentage of fleets that would follow this pattern, as shown in Figure 2-6, by addressing the lack of baseline data and using route-specific life cycle cost metrics to legitimize advanced technology vehicle adoption.

4.6 Institute Fuel Efficiency Training and Tracking

The final piece of operational advice for fleets to ensure successful adoption of advanced technology lies in the driver-side management of new vehicles. As one fleet manager put it, **"we now know that fuel consumption is heavily impacted by the behavior of the operators and that it may be possible to mandate certain fuel efficient behaviors through vehicle software and company policy on driver development, implementation, training, and follow-up."** This outlook highlights the need for complementary driver training and fuel economy tracking to roll-out alongside the advanced hardware and software on new vehicles. Without adequate instruction, drivers will not learn how to take advantage of fuel efficiency advancements, and without proper tracking, fleets will not know where to focus their fuel consumption reduction efforts.

4.7 Expand Regulatory Support for Innovative Tech and Idle Reduction

Based on the data identified in fleet interviews and this analysis, there is a meaningful amount of fuel reduction possible in specific applications where worksite idle reduction and other innovative technologies can be applied, including vocational hybridization. Regulatory requirements should encourage the use of innovative idle elimination or reduction technologies as well as advanced fuel reduction systems in applications where they can be beneficial. This support can come from increased levels of regulatory stringency to account for use of such systems, or by credit or incentive structures rewarding their use.

5. APPENDICES

Appendix A: Fleet Survey Results

Appendix B: Technology Area Descriptions

5.1 Appendix A: Fleet Survey Results

Question 1: Please identify the vehicle types in your fleet, you may select multiple options.

	Passenger Car	Passenger Truck	Light Commercial Truck	School Bus	Transit Bus	Refuse Truck	Single Unit Short-Haul Truck	Single Unit Long-Haul Truck	Combination Short-Haul Truck	Combination Long-Haul Truck
Fleet 1			X							
Fleet 2	X	X	X							
Fleet 3		X	X							
Fleet 4	X		X				X			
Fleet 5	X	X	X							
Fleet 6					X					
Fleet 7	X	X	X							
Fleet 8	X	X	X				X			
Fleet 9	X	X	X				X			
Fleet 10	X	X	X						X	
Fleet 11	X	X	X				X		X	
Fleet 12	X	X	X			X	X			
Fleet 13	X		X							
Fleet 14	X	X	X				X		X	
Fleet 15	X		X						X	
Fleet 16	X	X	X			X	X	X		
Fleet 17	X									
Fleet 18	X	X								
Fleet 19			X				X	X	X	X
Fleet 20	X	X	X							
Fleet 21	X	X	X				X			
Fleet 22	X	X	X	X			X			
Fleet 23	X	X				X			X	
Fleet 24	X		X		X					
Fleet 25	X		X							
Fleet 26	X	X	X		X	X	X	X	X	X
Fleet 27	X	X								
Fleet 28	X		X				X			
Fleet 29	X		X		X		X	X		
Fleet 30	X	X	X				X		X	
Fleet 31	X	X	X				X			
Fleet 32		X								
Fleet 33	X		X				X		X	X
Fleet 34	X	X								
Fleet 35							X		X	X
Fleet 36	X	X	X				X			
Fleet 37			X							
Fleet 38	X		X							
Fleet 39							X			
Fleet 40			X							
Fleet 41	X	X	X							
Fleet 42	X									
Fleet 43	X									
Fleet 44	X		X				X			
Fleet 45	X	X								

Question 2: Please list your fleet size per GVWR and/or total number of vehicles.

	Class 1: 6,000lbs and Under	Class 2a: 6,001-8,000lbs	Class 3: 10,001-14,000lbs	Class 4: 14,001-16,000lbs	Class 5: 16,001-19,500lbs	Class 6: 19,501-26,000lbs	Class 7: 26,001-33,000lbs	Class 8: 33,001lbs and Over	Total Fleet Size:
Fleet 1									
Fleet 2	52	19	16	0	0	11	0	8	0
Fleet 3	12					4	1		
Fleet 4									
Fleet 5	175	192	43	15	35	8	29	131	1400
Fleet 6								300	300
Fleet 7	35	470	115	5	153	5	50	200	1500
Fleet 8	205	135	13	4	5	7	2	7	
Fleet 9	45	337	11	2	1	2	0	3	400
Fleet 10	30	55	25	15	20	35	25	20	225
Fleet 11	150	45	65	40	25	20	15	25	
Fleet 12	76	34	6	4	9		29	3	247*
Fleet 13	350	25	25						400
Fleet 14	75	90	214	72	60	65	50	100	735
Fleet 15									
Fleet 16	350	180	125	75	50	65	65	25	935
Fleet 17	2000								
Fleet 18	25	10							
Fleet 19	30	10	26	20	15	140	60	125	
Fleet 20	102								
Fleet 21	145	8			12				
Fleet 22	61	74	12	12	5	3	11		
Fleet 23	30						6	50	86
Fleet 24	8	14	26			5	11		
Fleet 25	369	217	102	37	3				728
Fleet 26	105	5	10	5	5	25	30		
Fleet 27	1500								
Fleet 28	400	300		10				10	720
Fleet 29	250	13					1	1	
Fleet 30	8000	3500	300	500	300			100	12700
Fleet 31	89	75	25	24			38	25	378
Fleet 32	0	16	2						650
Fleet 33	0	1	3	0	0	1	2	20	27
Fleet 34	30								30
Fleet 35						5		50	55
Fleet 36	23	59	1		13		28	1	125
Fleet 37				3					
Fleet 38		2		1		1			
Fleet 39				2		2			
Fleet 40						2			
Fleet 41	2500	500							
Fleet 42									2
Fleet 43	3								
Fleet 44	2	5	5	8	2	4			
Fleet 45	5		2						

*Includes heavy and off-road equipment

Question 3: In general, are you supportive of regulation that requires manufacturers to provide higher fuel economy medium- and heavy-duty vehicles? Please explain.

	Yes	No
Fleet 1	X	
Fleet 2	X	
Fleet 3	X	
Fleet 4		X
Fleet 5	X	
Fleet 6	X	
Fleet 7	X	
Fleet 8	X	
Fleet 9	X	
Fleet 10	X	
Fleet 11	X	
Fleet 12	X	
Fleet 13		X
Fleet 14	X	
Fleet 15	X	
Fleet 16	X	
Fleet 17	X	
Fleet 18	X	
Fleet 19	X	
Fleet 20	X	
Fleet 21	X	
Fleet 22	X	
Fleet 23	X	
Fleet 24	X	
Fleet 25	X	
Fleet 26	X	
Fleet 27	X	
Fleet 28	X	
Fleet 29		X
Fleet 30	X	
Fleet 31		X
Fleet 32	X	
Fleet 33	X	
Fleet 34	X	
Fleet 35	X	
Fleet 36	X	
Fleet 37	X	
Fleet 38	X	
Fleet 39		X
Fleet 40		X
Fleet 41	X	
Fleet 42	X	
Fleet 43	X	
Fleet 44	X	
Fleet 45	X	

Aggregated Fleet Comments:

1. Lower Operating Cost

Fuel consumption is a high operating cost that can be acted upon. The relatively low price of oil will not last and current trade-offs are harming future operations. Rather, increasing vehicle and system efficiency results in higher fuel economy, which will lower overall operating cost.

2. Drive-Cycle Dependent Improvements

Due to highly variable on road and off road drive-cycles, special care must be taken to ensure that fleets have adequate purchasing options for higher fuel-economy vehicles that are applicable to their drive-cycle and fueling capability.

3. Reliability is Vital

Unreliable vehicles create unforeseen costs in downtime; therefore manufacturers need to ensure technologies do not reduce reliability and that their fuel economy goals are reachable, with deployments neither cost nor time-prohibitive to fleets. For fleets that buy used vehicles, new technologies are understandably scary because their long-term maintenance trends may be unknown or unpredictable.

4. Manufacturers Need Motivation

Fuel economy on commercial vehicles has not increased significantly in years because there has been no regulation either forcing or incentivizing manufacturers to improve efficiency. Manufacturers need to find ways to improve fuel economy, which will decrease emissions more than current emission control systems ever could while preparing the industry for the end of cheap fuel.

5. Environmental and National Security Benefits

Children should all have access to fresh air; emission reduction as a result of increased fuel economy is a humanitarian goal that affects everyone. Reduction in fossil fuel consumption carries the additional benefit of reducing dependency on volatile foreign oil markets.

Question 4: As they relate to your fleet operations, please rate the following fuel improvement technology areas on their usefulness from 1 (not interested) to 5 (extremely interested).

	Aerodynamics	Light-Weighting	Advanced Transmissions	Hybridization	Engine Improvements	Accessory Electrification
Fleet 1	3	3	4	3	3	3
Fleet 2	3	4	4	3	5	3
Fleet 3	4	4	4	4	4	2
Fleet 4	1	1	1	1	1	1
Fleet 5	3	4	3	4	4	5
Fleet 6	3	3	4	5	5	4
Fleet 7	1	3	4	5	5	5
Fleet 8	3	4	4	1	5	5
Fleet 9	3	4	3	2	4	3
Fleet 10	4	5	4	3	5	5
Fleet 11	1	3	4	2	5	3
Fleet 12	4	4	4	4	4	4
Fleet 13	3	3	3	1	3	3
Fleet 14	2	4	5	5	5	5
Fleet 15	2	3	3	3	4	3
Fleet 16	3	5	5	4	5	5
Fleet 17	4	4	4	4	4	4
Fleet 18	3	3	4	2	4	4
Fleet 19	3	3	4	2	4	3
Fleet 20	4	4	4	3	5	5
Fleet 21	4	4	4	4	4	4
Fleet 22	4	4	4	5	5	5
Fleet 23	3	5	5	1	5	4
Fleet 24	1	3	4	4	4	2
Fleet 25	3	4	5	5	5	5
Fleet 26	2	2	2	3	5	3
Fleet 27	3	4	4	5	5	4
Fleet 28	5	5	4	3	5	4
Fleet 29	3	2	3	2	3	2
Fleet 30	2	4	5	3	5	2
Fleet 31	5	4	4	2	2	2
Fleet 32	1	2	3	4	5	4
Fleet 33	5	4	5	5	5	5
Fleet 34	2	3	4	5	4	3
Fleet 35	3	1	3	4	4	4
Fleet 36	2	4	2	2	4	2
Fleet 37	3	3	4	5	4	4
Fleet 38	5	3	3	5	5	5
Fleet 39	1	3	4	4	4	2
Fleet 40	3	3	3	3	3	3
Fleet 41	3	4	4	5	5	5
Fleet 42	3	3	3	3	3	3
Fleet 43	5	5	5	5	5	5
Fleet 44	4	5	4	5	4	4
Fleet 45	3	3	3	3	3	3

Question 5: What are your concerns regarding higher fuel efficiency vehicles? You may select more than one answer.

	Productivity (Completing Routes)	Upfront Cost	Reliability	Maintenance	Performance
Fleet 1	X	X	X	X	X
Fleet 2	X	X	X		
Fleet 3		X	X	X	X
Fleet 4		X			
Fleet 5		X	X	X	X
Fleet 6	X		X	X	X
Fleet 7	X	X	X	X	X
Fleet 8		X			
Fleet 9		X	X	X	
Fleet 10		X		X	
Fleet 11		X	X	X	X
Fleet 12		X	X	X	X
Fleet 13				X	X
Fleet 14	X	X		X	
Fleet 15	X	X	X	X	X
Fleet 16		X			X
Fleet 17		X			X
Fleet 18	X	X	X	X	X
Fleet 19		X	X	X	X
Fleet 20					X
Fleet 21		X	X	X	
Fleet 22		X	X		X
Fleet 23	X		X	X	X
Fleet 24		X		X	
Fleet 25	X	X	X	X	
Fleet 26		X	X	X	
Fleet 27	X	X	X	X	X
Fleet 28		X	X		X
Fleet 29		X		X	X
Fleet 30		X			X
Fleet 31	X	X	X	X	X
Fleet 32		X	X	X	
Fleet 33			X	X	
Fleet 34		X			
Fleet 35		X		X	
Fleet 36	X		X	X	
Fleet 37		X	X	X	
Fleet 38	X	X		X	
Fleet 39		X	X		
Fleet 40	X	X	X	X	X
Fleet 41		X		X	
Fleet 42		X			
Fleet 43		X			
Fleet 44		X		X	
Fleet 45		X		X	

Question 6: Would you buy a vehicle that is initially more expensive than a conventional option, but that ultimately cost less to own and operate over its lifetime?

	Yes	No
Fleet 1	X	
Fleet 2	X	
Fleet 3	X	
Fleet 4		X
Fleet 5	X	
Fleet 6	X	
Fleet 7	X	
Fleet 8		X
Fleet 9	X	
Fleet 10	X	
Fleet 11	X	
Fleet 12	X	
Fleet 13	X	
Fleet 14	X	
Fleet 15		X
Fleet 16	X	
Fleet 17	X	
Fleet 18	X	
Fleet 19	X	
Fleet 20	X	
Fleet 21	X	
Fleet 22	X	
Fleet 23	X	
Fleet 24	X	
Fleet 25	X	
Fleet 26	X	
Fleet 27	X	
Fleet 28	X	
Fleet 29	X	
Fleet 30	X	
Fleet 31		X
Fleet 32	X	
Fleet 33	X	
Fleet 34	X	
Fleet 35		X
Fleet 36	X	
Fleet 37	X	
Fleet 38	X	
Fleet 39	X	
Fleet 40	X	
Fleet 41	X	
Fleet 42	X	
Fleet 43	X	
Fleet 44	X	
Fleet 45		X

Aggregated Fleet Comments:

1. Payback Period is Important…

The actual break-even point makes a difference on whether the initial investment could be made.

2. …Lifetime Analysis is More Helpful to the Business

But the bottom line does not end after vehicle purchase. Life cycle cost analysis should be a primary decision factor for new purchases, as long-term annual budgets will benefit from upfront planning and tight control on vehicle cost over many years.

3. Cost Savings Must be Attainable and Significant

Advanced technologies may require expensive repairs, which severely detract from any potential cost savings from reduced fuel consumption. The life cycle cost of these advanced vehicles must also be substantially less than other alternatives to offset the initial investment in the incremental vehicle cost.

Question 7: Please rate the importance of the following elements in a Total Cost of Ownership/Life Cycle Cost Analysis from 1 (not important) to 5 (very important).

	Upfront Cost	Ownership Period	Residual Value	Annual Maintenance Cost	Annual Mileage/ Hours	Annual Registration/ Fees
Fleet 1	5	5	5	5	5	5
Fleet 2	3	5	2	2	3	3
Fleet 3	4	4	4	5	4	4
Fleet 4	1	1	1	1	1	1
Fleet 5	4	5	5	4	5	2
Fleet 6	5	5	2	5	4	1
Fleet 7	3	5	3	5	3	2
Fleet 8	5	4	4	3	2	3
Fleet 9	5	5	5	4	5	3
Fleet 10	3	4	4	5	5	2
Fleet 11	4	4	2	5	3	1
Fleet 12	5	5	5	5	5	2
Fleet 13	4	3	3	4	3	3
Fleet 14	4	5	3	5	4	2
Fleet 15	5	3	3	5	3	3
Fleet 16	5	5	5	4	3	1
Fleet 17	5	5	2	4	4	4
Fleet 18	5	5	5	5	5	5
Fleet 19	4	3	4	5	4	3
Fleet 20	3	4	4	4	4	3
Fleet 21	4	4	4	4	4	1
Fleet 22	5	4	5	5	4	2
Fleet 23	5	5	5	5	4	1
Fleet 24	5	4	1	3	1	2
Fleet 25	5	5	3	4	4	4
Fleet 26	5	5	5	5	5	1
Fleet 27	5	5	5	5	5	3
Fleet 28	5	5	5	5	5	3
Fleet 29	3	3	2	3	1	1
Fleet 30	4	4	3	4	2	3
Fleet 31	5	5	4	5	4	1
Fleet 32	5	3	1	3	5	2
Fleet 33	3	4	4	4	2	3
Fleet 34	4	5	4	3	1	1
Fleet 35	5	4	1	4	5	4
Fleet 36	3	4	3	5	3	2
Fleet 37	3	3	2	5	5	4
Fleet 38	3	2	2	5	5	5
Fleet 39	5	4	2	3	3	2
Fleet 40	5	5	5	5	5	5
Fleet 41	4	4	1	5	4	4
Fleet 42	5	5	5	5	4	1
Fleet 43	5	5	5	5	5	5
Fleet 44	5	4	4	4	3	1
Fleet 45	5	5	3	5	4	3

Are there any other elements you think are required in an evaluation?

Downtime costs may be relevant when they affect productivity and the requirement for vehicle spares. Where possible, analysis should also include evaluation of the technology company itself, assessing their stability and long-term prospects, as these are important to ensure service and replacements will be available for the fleet.

Question 8: Do you currently use TCO/Life Cycle Analysis evaluations in your procurement? If not, how do you make procurement decisions? Please select all that apply.

	Yes	No	Simple Payback	Stay with Known Brand	Lowest Upfront Cost	Other
Fleet 1		X	X	X	X	
Fleet 2	X					
Fleet 3		X	X	X		
Fleet 4		X	X			
Fleet 5	X					
Fleet 6		X				X
Fleet 7	X					
Fleet 8		X			X	
Fleet 9	X					
Fleet 10		X		X		
Fleet 11		X			X	X
Fleet 12		X			X	X
Fleet 13		X		X		
Fleet 14	X					
Fleet 15		X		X	X	
Fleet 16	X					
Fleet 17	X					
Fleet 18	X					
Fleet 19		X	X	X		
Fleet 20		X	X			
Fleet 21	X					
Fleet 22	X					
Fleet 23	X					
Fleet 24	X					
Fleet 25		X		X	X	X
Fleet 26	X					
Fleet 27	X					
Fleet 28	X					
Fleet 29	X					
Fleet 30	X					
Fleet 31	X					
Fleet 32		X				
Fleet 33	X					
Fleet 34		X			X	
Fleet 35		X		X	X	
Fleet 36	X		X	X		
Fleet 37		X				
Fleet 38	X					
Fleet 39		X	X			
Fleet 40		X				X
Fleet 41	X					
Fleet 42		X	X			
Fleet 43		X				
Fleet 44		X				X
Fleet 45		X				X

Other Procurement Decision Reasons:

1. Government Bid Contracts

Many public fleets are required to conduct a bid and vetting process for their vehicle purchases, which combine many inputs for decision-making, possibly including a Total Cost of Ownership comparison.

2. Specialty Vehicles

Specialty vehicles for unique applications often have limited options and therefore sufficient data may not be available to conduct an accurate Total Cost of Ownership comparison between two or more vehicles.

Question 9: If you don't currently use TCO/LCCA evaluations and saw an operational benefit from these models, would you consider using them?

	Yes	No
Fleet 1	X	
Fleet 2		
Fleet 3	X	
Fleet 4		X
Fleet 5		
Fleet 6		
Fleet 7		
Fleet 8	X	
Fleet 9		
Fleet 10		X
Fleet 11	X	
Fleet 12	X	
Fleet 13		X
Fleet 14		
Fleet 15	X	
Fleet 16		
Fleet 17		
Fleet 18		
Fleet 19	X	
Fleet 20	X	
Fleet 21		
Fleet 22		
Fleet 23		
Fleet 24		
Fleet 25	X	
Fleet 26		
Fleet 27		
Fleet 28		
Fleet 29		
Fleet 30		
Fleet 31		
Fleet 32		
Fleet 33		
Fleet 34	X	
Fleet 35	X	
Fleet 36		
Fleet 37		
Fleet 38		
Fleet 39		X
Fleet 40	X	
Fleet 41		
Fleet 42	X	
Fleet 43		
Fleet 44	X	
Fleet 45		X

Question 10: Please rate the most useful vehicle purchase comparison metrics for your business from 1 (not useful) to 5 (very useful).

	Incremental Cost	Net Present Value[1]	Lifecycle Cost[2]	Lifecycle Cost per Mile[3]	Simple Payback/ ROI[4]
Fleet 1	5	4	4	4	4
Fleet 2	3	1	1	3	4
Fleet 3	3	3	4	5	5
Fleet 4					
Fleet 5	4	3	4	4	3
Fleet 6					
Fleet 7	2	2	4	4	3
Fleet 8	2	1	4	3	5
Fleet 9	2	3	4	3	3
Fleet 10	3	3	2	3	4
Fleet 11	3	2	5	3	3
Fleet 12	3	3	5	2	3
Fleet 13	3	4	4	3	3
Fleet 14	3	3	5	4	4
Fleet 15	3	3	5	4	2
Fleet 16	5	5	3	4	3
Fleet 17	4	4	4	4	4
Fleet 18	5	5	5	5	5
Fleet 19	3	3	4	4	3
Fleet 20	3	3	3	4	4
Fleet 21	3	4	4	4	4
Fleet 22	4	3	5	5	4
Fleet 23	4	1	3	5	5
Fleet 24	4	2	5	1	1
Fleet 25	5	3	5	5	4
Fleet 26	3	3	5	3	3
Fleet 27	3	3	5	5	5
Fleet 28	3	2	5	5	4
Fleet 29	1	2	3	2	3
Fleet 30	3	2	3	2	4
Fleet 31	3	3	5	5	4
Fleet 32					
Fleet 33	4	4	3	3	3
Fleet 34					
Fleet 35	4	4	5	5	4
Fleet 36	3	2	3	3	4
Fleet 37					
Fleet 38	2	5	4	5	3
Fleet 39	3	2	3	4	3
Fleet 40	3	2	5	3	3
Fleet 41	4	4	4	4	
Fleet 42					5
Fleet 43					
Fleet 44	3	3	4	4	4
Fleet 45	3	3	3	3	3

1 — Cash inflows plus conversion of future costs into present value, minus acquisition costs

2 — ex. $500,000 over 10 years

3 — ex. $0.50/mi

4 — ex. 3 years

5.2 Appendix B: Technology Area Descriptions

Engine Optimization
Use engine improvement technologies such as engine design and combustion processes, engine friction and parasitics, predictive engine controls, downsized engine and engine down-speeding to increase the brake thermal efficiency of the engine.

Waste Heat Recovery
Recover waste heat from the engine exhaust and other heat exchangers (EGR coolers) to improve the overall thermal efficiency of the engine.

Transmission & Driveline Improvement
Integrate transmission and driveline improvements such as automated manual transmission and automatic transmission to reduce opportunity for operator error, reduce driveline losses and enable engine optimization improvements such as engine down-speeding and downsizing.

Hybridization
Use a secondary drive system such as electric motor/generator drive systems or hydraulic pump/motor drive systems to support or replace the internal combustion engine. Hybridization includes electrically-assisted idle shutdown, micro, mild, parallel, series, and dual-mode hybrid.

Improved Aerodynamics
Use aerodynamic fairings and devices to reduce the aerodynamic drag of the vehicle.

Electrified Auxiliaries
Use electricity instead of mechanical energy to drive accessories such as oil pump, water pump, power steering pump, A/C compressor, cooling fans which can consume up to 9% of the energy used in a conventional truck.[15]

Wheels and Tires
Use low rolling resistance and/or wide-base single tires and tire pressure monitoring to minimize rolling resistance.

Weight Reduction
Use lightweight materials (such as plastics, aluminum, high strength steel, magnesium, composites…) across body, chassis and interior of vehicle to reduce the overall mass of the vehicle.[16]

[15] California Environmental Protection Agency, Air Resources Board. Medium and Heavy-Duty Battery Electric Vehicles, Technology Assessment. September 2, 2014. Sacramento, CA. http://www.arb.ca.gov/msprog/tech/presentation/electrictrucks.pdf. Accessed on 04/22/2015.
[16] Ricardo. Engine Technology Roadmap for NOx, CO2 Reductions In Class 7 – 8 Commercial Vehicles. June 6, 2013.