Barriers to the Increased Adoption of Fuel Efficiency Technologies in the North American On-Road Freight Sector

Report for the International Council for Clean Transportation

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July 2013

Acknowledgements:

This project was done with support and funding from the ICCT. The authors are also grateful for the research contributions and reviews of Tessa Lee and David Schwartz of the Carbon War Room, the assistance of Kevin Rutherford of Let's Truck and all of the participating owner-operators and individuals from the fleets, supply chain companies and dealers for their time and candidness. The expert advisory committee of Nigel Clark, Bruce Stockton, and Susan Mazur-Stommen also provided valuable insights at the various stages of the project, as did Ben Sharpe, Rachel Muncrief, and Nic Lutsey of the ICCT.

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Executive Summary

Worldwide, light-duty passenger vehicles and heavy-duty vehicles such as tractor-trailers, which are primarily for freight transport, account for about three-quarters of all transportation energy use and climate impacts (IEA 2009). Reducing fuel consumption and emissions of CO_2 and other greenhouse gases (GHGs) from road transport lessens the negative climate and energy security impacts of the transportation sector. In the US, heavy-duty vehicles account for 4% of the vehicles, but are responsible for over 20% of the total transportation petroleum use, with the long-haul trucking sector responsible for 70% of that total (DOE 2009). Until recently, worldwide efforts to reduce energy consumption through improved vehicle efficiency have been focused primarily on light-duty vehicles. As passenger vehicles become significantly more fuel efficient in the coming years, the relative importance of the heavy-duty sector will continue to grow. The potential impact of widespread adoption of efficiency technologies in the freight sector is significant. Many efficiency technologies are commercially available to improve the fuel efficiency of tractor-trailers, yet many of the technologies are slow to be adopted.

From November 2012 through May 2013, the North American Council for Freight Efficiency (NACFE) and Cascade Sierra Solutions (CSS) conducted a study for the International Council for Clean Transportation (ICCT) to better understand the existing barriers that are impeding the adoption of fuel-saving technologies for the on-road freight sector. The project's objective is to seek a deeper and broader understanding of the critical questions in the decision-making process related to the adoption of these technologies.

Data for this project was collected using in-person interviews, focus groups, and online surveys of a number of stakeholders throughout the on-road freight industry. The stakeholders that were chosen play important roles in their respective companies in the decision-making process about technologies for tractor trucks and trailers. The team engaged not only end users (i.e. trucking fleets and owner-operators), but also stakeholders throughout the trucking value chain. The end users included large (i.e. companies that own more than 1,000 trucks) and medium (100-1,000 trucks) for-hire fleets, private fleets, lease/rental fleets, fleets that exclusively purchase used trucks, and owner-operators. The other stakeholders included companies within the truck and trailer supply chains that manufacture, sell, integrate, and service fuel-saving technologies. Altogether, the companies included leading engine and transmission manufacturers, aerodynamic device developers, tractor and trailer builders, truck dealers, fleet operators, shipping companies, and owner-operators. In all, in-person or telephone interviews were conducted with 40 representatives within 29 companies, and, in addition, responses from nearly 1,900 owner-operators around the country were received via an online survey.

Upon evaluation of the survey and interview responses, several barriers were consistently identified across all of the stakeholder groups. The five predominant barriers are:

- Lack of credible information

- Uncertainty around the amount of time needed for technologies to pay for themselves in terms of fuel savings (i.e. payback time)
- Lack of access to capital cost to invest in new technologies
- Questions as to the reliability of new technologies
- Lack of availability of fuel-saving technologies from preferred OEMs or component suppliers

These five barriers do not exist in a vacuum and are inherently linked in many ways, which is illustrated in Figure 1. It was found that lack of credible information was *the* overarching barrier, which has bearing to some extent on all the other barriers. For example, if there is a lack of credible information with respect to verifying the real-world fuel-saving potential and/or reliability of a technology, this makes accurate calculations of payback time a challenging task. Furthermore, this lack of information can also influence the ability to obtain capital to invest in new technologies. Taken together, uncertain fuel savings and reliability as well as lack of access to capital contribute to slow technology adoption. This depressed demand can result in diminished manufacturer investment in new technology development, which can lead to a reduced number of product offerings. Finally, this lack of technology availability has a feedback effect by reducing technology uptake, which in turn limits the ability for technology performance data to be generated.

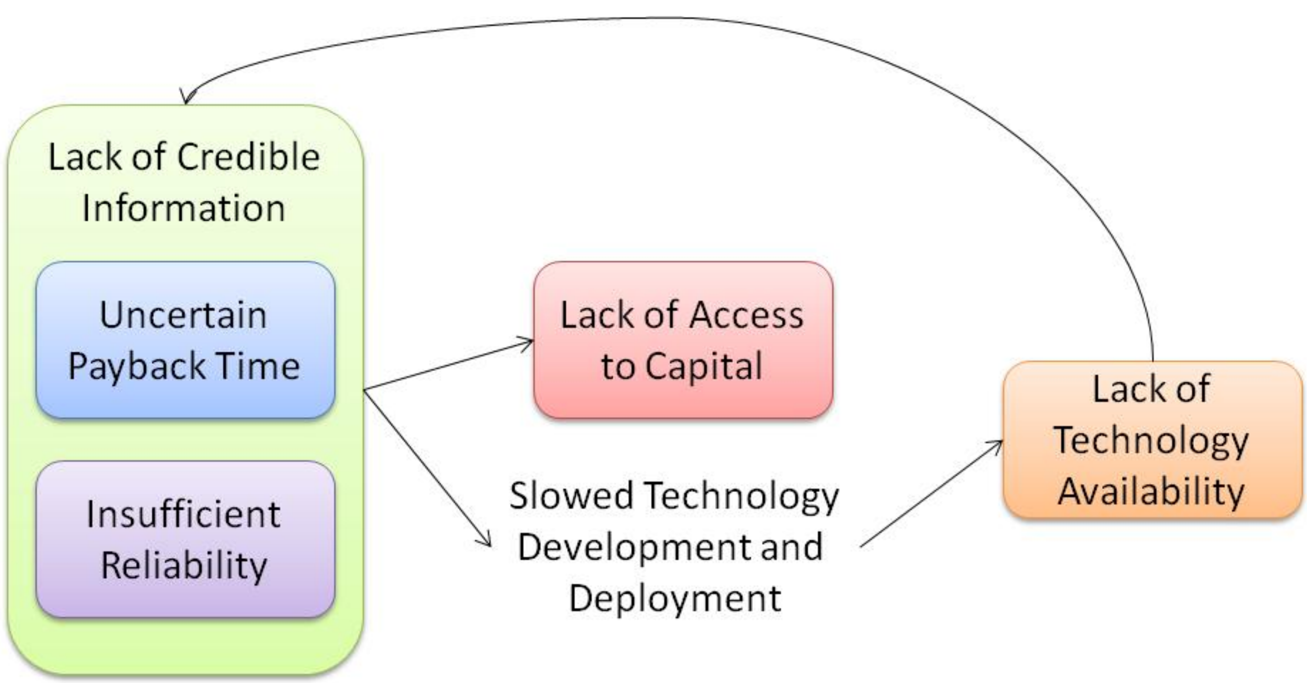

Figure 1: Overview of Barriers

While these five barriers were identified as somewhat universal for the entire pool of stakeholders, not all stakeholders are impacted to the same extent by each barrier. Based on the diverse input from the study, there were a number of general differences in perspectives among the stakeholders about the adoption of efficiency technology. All stakeholder groups had a high level of consensus with one another on the barriers of lack of credible information and uncertainty around payback. Insufficient capital was a much bigger issue for the small end users (medium fleets, used truck fleets, and owner-operators) than their larger company counterparts, who stated that their organizations would commit the capital if there is a high degree of confidence that the technology will pay back. End users were generally more critical of new product reliability than the component manufacturers or tractor and trailer original equipment manufacturers (OEMs). Concerning the lack of product availability as an important barrier, all of the end users as well as the manufacturers of individual technologies were very outspoken about this issue. The truck and trailer integrators, on the other hand, did not see this as a significant issue.

Key findings

Payback time. This study suggests that all fleets make decisions to buy new technologies using a payback calculation, and the manufacturing industry also uses payback time as a key metric in determining what products to develop and bring to market. Though the responses varied, the stated expectation for payback time was typically half of the truck ownership cycle. Interview responses showed that large for-hire fleets generally purchase new trucks and operate them four to six years, which translates to a payback time expectation of two years so that in the final two or more years of truck ownership, the fleet can see a return on investment. Truck and trailer OEMs and component suppliers customarily use two years or less as the benchmark for payback time, which signals that the requirements of the fleets with the shortest ownership cycles are driving the product development process for the entire industry. Payback calculations seem to vary in terms of the parameters that are included in the calculation and tend to be rather conservative to reflect the uncertainty surrounding the fuel savings, reliability, durability, and additional maintenance or operations impacts that are associated with a technology.

Capital costs. Some fleets shared that access to capital is an issue, even if the fleet has confidence that a fuel-saving technology delivers a payback for their operations. New equipment costs (adjusted for inflation) have increased significantly over the past 10 years, and the money a fleet can spend on fuel-saving technologies compete against driver amenities to better attract and retain drivers and other new technologies to improve safety, communications and routing.

Credible information. Verifying performance in the early stages of technology deployment is challenging, and a multitude of independent testing efforts by multiple fleets and manufacturers is commonplace. Conflicting word-of-mouth experiences about technology performance often causes confusion with fleets that are interested in adopting a technology and presents challenges to manufacturers and suppliers that are attempting overcome the mistrust and high degree of risk aversion that is pervasive in the trucking industry. Fleets seem to understand that it is difficult to stay abreast of all the technologies being developed by performing all of the testing themselves, but they rarely have full confidence in external results.

Reliability. High reliability is a crucial factor for an end user to purchase a technology. Early adopter fleets understand that new products often require improvements in later generations. However, based on interview responses, insufficient reliability with some recent new product launches has introduced concern and skepticism, likely delaying or eliminating demonstration projects and adoption decisions.

This study was solely focused on characterizing the adoption barriers for fuel-saving technologies for tractor-trailers, not exploring strategies for addressing or overcoming them. However, the findings of this project can lead to more in-depth analysis of the policy measures and other ways to encourage increased development and deployment of fuel-saving technologies and practices in the trucking sector.

I. Introduction

The trucking sector has proved successful in improving efficiency over the decades. The total cost of moving goods in the U.S. as a percentage of Gross Domestic Product (GDP) has been cut in half since the early 1980s, from 18% to around 9%, according to ACT Research. While, there are likely a number of factors that have contributed to this decline in costs, including advances in logistics efficiency (i.e. routing, load management, packaging, etc.) and infrastructure improvements, increases in tractor-trailer fuel efficiency have likely been an important contributor in decreasing the overall costs of on-road goods movement. However, many challenges continue to exist for trucking fleets, owner-operators, and the companies that manufacture and sell tractor trucks, trailers, and equipment used by these heavy-duty vehicles. Some of the challenges for the industry include driver shortages, high rates of driver turnover, rising costs of fuel and new equipment and increasingly stringent regulations targeting criteria pollutant emissions as well as fuel efficiency and greenhouse gases (GHGs).

The barriers to developing and deploying fuel-saving technologies are the subject of this study. Figure 2 below shows a 2012 estimate of the cost breakdown for long-haul trucking operations in dollars per mile according to the American Trucking Research Institute (ATRI 2012). Fuel costs, driver salaries, and the costs of the trucking equipment dominate the overall costs of Class 8 tractor-trailer use. Capital equipment costs have been rising sharply driven by a number of factors, including the introduction of federal criteria pollutant emissions regulations that have required reductions in particulate matter and nitrogen oxide emissions of roughly 90% over the past 10 years. According to Manufacturer Suggested Retail Price (MSRP) data collected for four representative vehicles, the price of tractor trucks increased by roughly 14% (in 2012 dollars) between model years 2003 and 2012 (Price Digest 2013). However, over this same time period, diesel fuel has had a much larger percent increase, rising from an average of $1.88 per gallon in 2003 to $3.97 in 2012 (both values given in 2012 dollars), which is an increase of 111% (EIA 2013, BLS 2013). For context, a new sleeper tractor purchased in 2013 for $125,000 consumes roughly $125,000 in fuel in about 18 months, assuming the tractor drives 120,000 miles per year at $4 per gallon diesel and 6 miles per gallon.

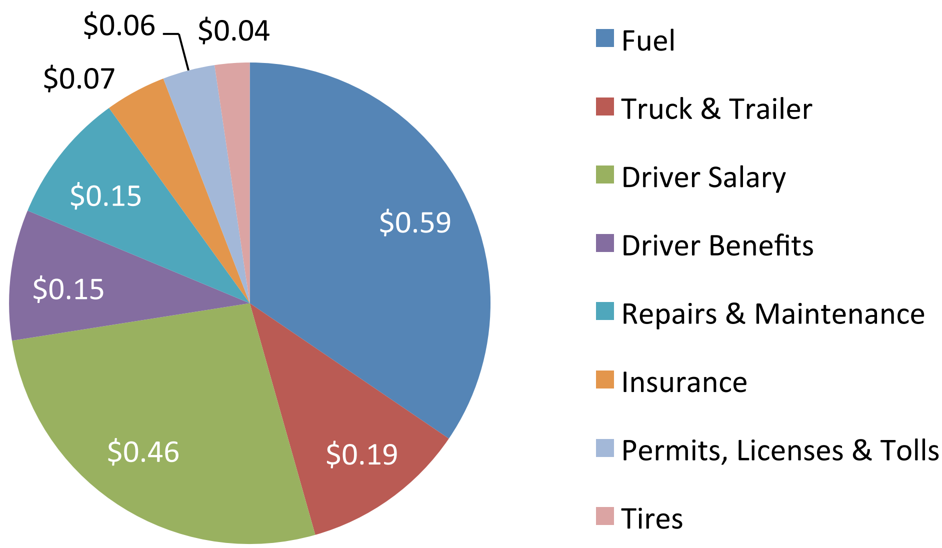

Figure 2. Cost of Trucking- Dollars per Mile

Source: American Trucking Research Institute, 2012

With fuel representing such a large part of the operating costs for fleets and owner-operators, much attention is now focused on improving the fuel efficiency of these Class 7 and 8 tractor-trailer units. New technologies are emerging from established and new equipment manufacturers; and some fleets are aggressively investigating, testing, and in some cases adopting these new efficiency technologies for their tractors and trailers. In addition, new fuel efficiency and greenhouse gas emission regulations have been adopted in the U.S. and Canada for model year 2014 and beyond.

Two U.S.-centric studies were recently completed that investigate the extent to which there are cost effective efficiency technologies for over the road trucks that may not being adopted today. They include work completed by TIAX (TIAX 2009) and the National Academy of Sciences (NAS 2010). The TIAX work formed the technical basis for much of the NAS study, and this research was a comprehensive assessment of technology potential and costs for both long-haul trucks as well as a number of different heavy-duty Vehicle categories. These studies reported that there were technologies available for long-haul tractor-trailers to improve their fuel consumption by over 50%. Figure 3 below shows the fuel-saving potential for tractor-trailers broken down by technology area: engines, aerodynamics, tires and wheels, weight reduction, hybridization, transmissions and driver coaching.

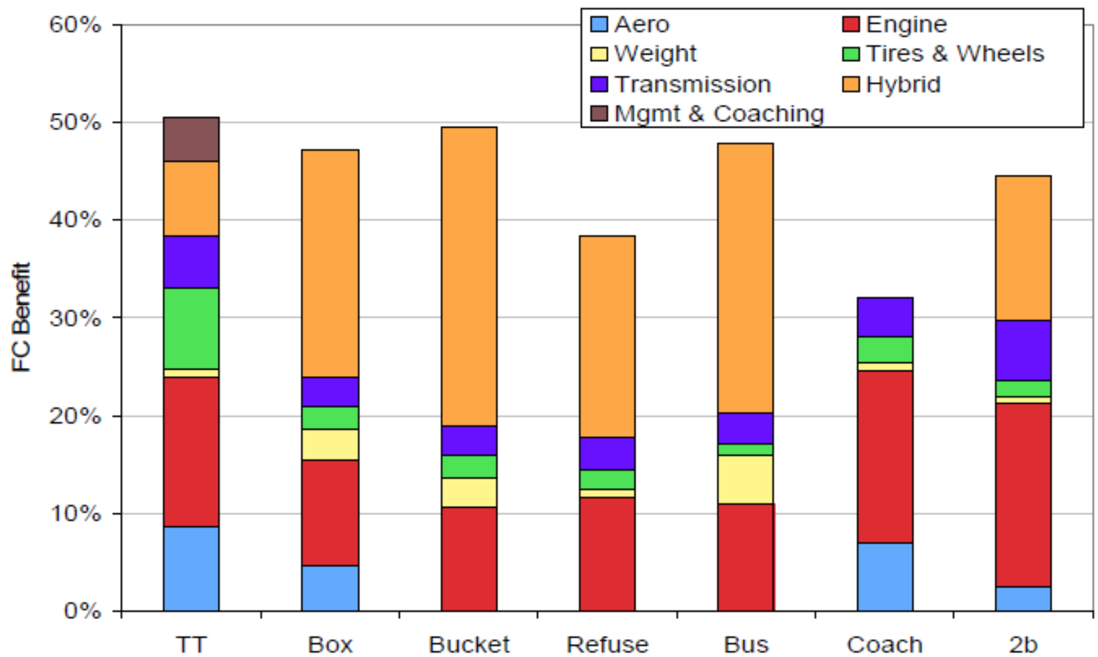

Figure 3. 2015 – 2020 New Vehicle Potential Fuel Savings Technologies

Source: NAS 2010

In August 2011, the U.S. Environmental Protection Agency (EPA) and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) finalized a national program to reduce greenhouse gases (GHGs) and improve fuel efficiency of medium- and heavy-duty vehicles. The program affects model year (MY) 2014 to 2018 vehicles, and tractors are a key component of the rule. Trailers were not addressed in this Phase 1 rulemaking. The stringency for tractors ranges between 10% and 23%, depending on the vehicle configuration and gross vehicle weight rating (i.e. Class 7 or 8). The standards are designed to encourage deployment of commercially available technologies, and for tractors, the agencies estimate that the technologies that will be deployed as a result of the rule have a payback time of 2 years or less, which reflects the agencies' cost-effectiveness targets for the Phase 1 regulation.

Literature review

Much attention in the social sciences has been paid to the "energy paradox," the phenomenon that some energy efficiency measures are not being implemented in places where it is cost-effective to do so (Shama 1983). However, most of this work has been focused on goods used by consumers (for example, efficiency improvements in household appliances and passenger vehicles) rather than goods used by businesses.

Nonetheless, the idea of the energy paradox offers an important foundation for studying market barriers in the on-road freight sector.

In trying to understand what drives and inhibits the diffusion of new technologies, economists have considered how adoption is shaped by both awareness of new technologies and changing costs and benefits for individual purchasers (Jaffe and Stavins 1994). While these processes may be different for each technology and sector, economists have identified a number of market barriers that inhibit diffusion. For energy efficiency technologies in particular, these include several market failures and other difficulties that drive the energy paradox.

Firstly, a common barrier to increased energy efficiency is a lack of credible information about technologies. If information on energy efficiency is underprovided, this constitutes a market failure (Jaffe and Stavins 1994). However, this barrier could also simply be due to the high costs faced by each actor of obtaining information and performing cost-benefit calculations. Another major market failure is the principal-agent, or split-incentive problem, which exists if the actor that uses energy does not also pay for energy or energy efficiency investments, leading to an overuse of energy or an underinvestment in energy efficiency (Jaffe and Stavins 1994).

Several barriers also relate to the uncertainty inherent in making energy efficiency investments. For example, technology will be underused if firms are unable to access credit due to lack of money available to invest, or if firms are unable to communicate the benefits of their investment to a creditor or when reselling the unit. Due to uncertainty about a technology's effectiveness and the prices of a technology and energy, a firm or consumer could rationally decide that the benefits are too uncertain, or that it makes sense to preserve its "option value," the ability to wait to see if a better investment would be available in the near future (Ansar and Sparks 2009). Other studies have focused on behavioral drivers of the energy paradox (Ansar and Sparks 2009), although these have been focused on consumer goods.

In researching available technologies for heavy-duty vehicle efficiency, the project team reviewed other studies related to the barriers to technology adoption in commercial vehicles used in regional and long-haul goods movement. Several studies have looked at market barriers particularly for energy efficiency in the on-road freight sector, although it has historically received less attention than other sectors. Most studies have used surveys and interviews to assess market barriers. With the exception of the split-incentive problem, studies found market barriers to be more significant for smaller companies and technologies that require a significant capital investment.

A study of the European freight sector commissioned by ICCT found evidence that there are typically greater barriers to technology improvements, with many trucking companies opting to investment in operational improvements instead. Another finding was that smaller firms had less ability to research technological improvements and to protect against growing fuel prices (CE Delft 2012). Similarly, an online survey of trucking companies in Finland found that effective but simple actions (i.e. idling reduction, speed limitation, checking tire pressure) were implemented more often than those requiring larger investment or knowledge (especially if there are a lot of options available, as is the case with motor oils and tires) (Liimatainen et al. 2012). NACFE (2011) studied adoption rates in the United States fleet of a range of technologies, identifying high costs of information, difficulty with monitoring costs, and lack of increased resale value due to energy efficiency as inhibiting the adoption of certain technologies.

Goodyear Dunlop (2012) interviewed fleet managers in the European Union and found that nearly half of respondents, especially smaller companies, said they lacked the sufficient knowledge of the technology available to increase fuel efficiency. Real-world evaluation was often cited as the only reliable way to test for fuel efficiency, as companies reported lack of trust in fuel savings claims made by OEM's. These risks caused firms, especially smaller ones, to focus on smaller investments involving maintenance and retrofitting rather than purchasing new trucks. The Carbon War Room (2012) identified large upfront costs and small profit margins in the trucking sector, truck leasing practices, and a lack of awareness and trust in fuel efficiency upgrades as barriers in the United Sates. Similarly, Ellram and Golicic (2011) found that lack of information and difficulty financing upgrades were major barriers, especially for smaller firms.

Several studies also found evidence of contract structures that created split incentive problems. Of the respondents for the CE Delft study (2012), a roughly 50% of trucking companies used fuel surcharges and/or open book contracts, which allow firms to directly pass on fuel costs (or additional fuel costs after surpassing a defined threshold) to the shipping (or client) entity. In another example of how contract structures can create split incentives, the Carbon War Room (2012) found that leased trucks tended to be less energy efficient.

The findings from these previous studies provided the team insights for designing the data collection and analytic framework for this project. From the various studies, a number of findings became clear. Foremost, it was clear that there are many technologies for the tractor-trailer that, when combined, can dramatically increase fuel efficiency. Efficiency technologies are available for the powertrain (e.g., engine, accessories, and transmission) as well as tractor and trailer load reduction (e.g., lightweighting, aerodynamics, tires) (NAS, 2009; US NREL, 2013). Many of these technologies are available not only for new heavy-duty vehicles, but also for existing in-use fleet (Transplace, 2012; NACFE, 2013; CWR, 2012; Ellram and Golicic, 2011). Several researchers have begun to better understand why the efficiency technologies are not being more widely adopted in the market place (e.g., CE-Delft, 2012).

There are, however, significant barriers to adopting these technologies. This study's intent is to work with the industry to identify and better understand the barriers that exist to adopting these technologies on North American tractors and trailers. The objective of the project is to use interviews and surveys of various entities within the trucking sector to better understand the specific barriers that exist in deploying technologies that improve fuel efficiency in Class 7 and 8 tractor-trailers

II. Study Design and Methodology

This section outlines the major elements and rationale for the study design and methodology. The methodology for the study was developed, in collaboration with ICCT and involved surveying eleven stakeholder groups (e.g., large fleets, owner-operators, shippers, manufacturers). Overall, the surveys included in-person interviews and focus groups, conference calls, and online input from various stakeholders within the long-haul trucking industry. As part of the processing of the high volume of input, the study team processed the interview and survey results from dozens of questions into overall themes during a findings workshop conducted in February 2013.

Survey design

The focus of the person-to-person interviews and online survey was to engage individuals from companies that are involved in the use, development, manufacturing, sales, and aftermarket support for tractor and trailer technologies. To better reach companies that are actively making decisions regarding fuel-saving technologies, the project team targeted "lead users" for the in-person and teleconference interviews. *Lead users* is a term developed by Professor Eric von Hippel (Von Hippel 2005) of the Massachusetts Institute of Technology and refers to companies that are "ahead of the majority of users in their populations with respect to an important market trend and expect to gain relatively high benefits from a solution to the needs they have encountered there."

During and after the interviews, the study team worked with lead users to ensure the data collected during interviews clearly reflects their perspectives on the barriers to technology adoption, their own decision-making process with regard to truck and trailer technology, and the other companies that are connected to all aspects of their industry. As aforementioned, lead users were targeted from two general areas – end users and industry supply chain – and several stakeholder subgroups were identified within these areas. End users, as defined in this study, are those companies or individuals who buy and operate commercial tractor trucks. Many of the fleets interviewed for this project have been early adopters of a number of fuel-saving technologies for both tractors and trailers. Individuals within companies who make the actual purchase decisions whether or not to invest in technologies for improved fuel efficiency were targeted for interviews. This end user group includes fleets (large, medium, private/retail, lease/rental, used truck) and owner-operators (i.e., as defined in this study, those individuals or companies who own and operate less than 5 trucks). The second area, the industry supply chain, includes companies that support the development, sale and delivery of the technologies into the marketplace. Within this area, the project team targeted major truck original equipment manufacturers (OEMs) as well as key component suppliers (e.g. engines, transmissions, tires, aerodynamic devices) that are responsible for bringing various fuel-saving technologies to market. In addition, truck dealers were also included in the project.

Data was received and analyzed from the groups shown in

Table 1. Companies participating in this study included: A&M Transport Inc., ATDynamics Inc., Bettendorf Trucking Enterprises, C.H. Robinson Worldwide Inc., C.R. England, Cummins Inc., Daimler Trucks North America LLC, Decker Truck Line Inc., Eaton Co., Freight Wing Inc., Frito-Lay North America Inc., Gordon Trucking Inc., Great Dane, Hyundai Translead, Michelin North America Inc., Navistar Inc., Peloton Technology Inc., Peterbilt, Ryder, Safeway Foods, Schneider, Smart Truck, Sturman Industries, Transfreight, United Parcel Service of America Inc., Volvo Trucks, Werner Enterprises, Witte Brothers Exchange Inc., and YRC Worldwide Inc. Owner-operators from two distinct solicitation groups participated in online surveys: customers of Cascade Sierra Solutions financing tools and Kevin Rutherford's Let's Truck Sirius XM radio membership.

Table 1. Industry Stakeholder Groups Surveyed

Area	Stakeholder Group	Comments
End users	Large fleets	For –hire trucking companies with 1,000+ trucks
	Medium fleets	For –hire trucking companies with 100-1,000 trucks
	Used fleets	Purchase only used trucks for their operations
	Retail-Private fleets	Operate trucks to haul goods they manufacture and/or distribute and sell
	Lease and Rental fleets	Lease and rent trucks to other end users
	Owner-operators (<5 trucks)	Independent, small businesses
Supply chain	Tractor OEMs	Builders of tractors who integrate technologies
	Trailer OEMs	Builders of trailers who integrate technologies
	Established component manufacturers	Established, mature suppliers to the trucking industry
	New technology suppliers	Emerging manufacturers with new technologies, often startup firms
	Shippers and Logistics	Freight brokers linking shippers and carriers
	Truck Dealers	Sales, aftermarket, repair and customer support

Stakeholder descriptions

Large Fleets – These customers generally own in excess of 1,000 class 8 tractors and operate for-hire as TL (truck load) or LTL (less than truck load) carriers. For these fleets, dry vans are the predominate trailer type, followed by refrigerated trailers and intermodal chassis. They operate sophisticated routing and logistics operations and maintain their equipment at their own service facilities, but use other service locations frequently as the trucks are randomly dispersed around the geography serviced by the fleet. It is common for drivers to be on the road for up to three weeks, returning home for a few days before leaving again. A vast majority of the tractors have sleepers with sophisticated communications, entertainment and other amenities for the drivers who essentially “live” in their trucks. As described in more detail in the findings section below, tractors are generally traded every 4-6 years to ensure maximum uptime and fuel efficiency. Therefore, high residual values are important to their business model. Most of these companies operate in all lower 48 states (or all provinces of Canada), and some do business in Mexico. They primarily use company drivers but many contract owner-operators for specialized freight or to handle seasonal or peak load periods. Company driver turnover is an issue and averages around 100% per year over the economic cycle. Some of these fleets utilize significant numbers of owner-operators as independent, dedicated contractors to manage variability in their business.

Retail/Private Fleets – These companies are either in the business of hauling their own products between their plants and distribution centers and to the retail market or in the retail package delivery business. Private fleets can be in the manufacturing, wholesale, retail, food or beverage business. In addition to class 8 tractors many operate class 5-7 delivery units on a local basis. Typically the retail/private fleet who owns their trucks keeps them 7-10 years or even longer. Nearly half of all Private fleets utilize full service maintenance leasing as their primary business in not trucking and they do not want to invest in their own service facilities. Driver turnover is quite small, around 22% versus about 100% for for-hire fleets, as the drivers are company employees with benefits, including retirement and 401k plans. About 90% of the tractors are daycabs as the routes are designed for the drivers to return to a company facility each night. Private fleets will tend to consider retrofitting devices on their fleet as they keep their vehicles for most if not all of their useable life, giving more time to realize the benefits of the devices.

Medium Fleets – They operate over 100 but less than 1,000 tractors primarily in the Truck Load for-hire segment of the business. Many operate on a regional basis or haul specialized freight nationwide. Trailers include dry freight & refrigeration vans and platform (flatbed) trailers for hauling equipment or manufacturing materials. They have many of the same challenges as their larger for-hire counterparts, but driver turnover tends to be lower as the smaller companies can better interact with the operators.

Lease/Rental – This vocation includes two very large NAFTA firms, Ryder and Penske, some regional companies and truck OEM associated groups of independent truck dealers. They purchase class 3-8 trucks to rent or lease to others (primarily to private fleets). Rental trucks are for shorter terms and leased trucks (charged at a monthly and per mile basis) for longer terms. Lease companies handle the specifying, purchasing, financing, licensing and maintenance for their own trucks. Their service facilities also provide washing and fueling for their customers. Many leasing companies operate their own resale lots due to the short trade cycle and high volume of trucks in this vocation, and may function as a fleet utilizing equipment that they choose not to sell. Leasing companies are known for their high level of understanding of how the equipment performs, particularly in its reliability and durability. Due to the fact that they have the exposure in the lease contract for poor reliability but not for fuel efficiency, these companies monitor, track and make purchase decisions with sophisticated tools to thoroughly understand every component’s reliability.

Used Fleets – Fleets who primarily purchase used trucks in the for-hire business are considered used fleets for this study. They typically operate under 200 units, primarily class 8 tractors, and have shorter hauls than the large fleets as many operate on a regional basis. Their business model is focused more on lower cost freight thus the dependence on lower priced used trucks. They depend on the first truck purchaser's specification expertise and their own understanding of the duty cycles they operate in when they select these used trucks. These fleets might consider retrofits and tend to perform much of their own maintenance, as they are attempting to extend the equipment's usable life.

Shippers and Logistics – Shippers are characterized as firms who need to move freight. They are the customers of the fleets/carriers.Over the past few decades a new brokering enterprise has emerged known as Third-party Logistics providers. These firms work between Shippers and Carriers to make efficient decisions for using equipment to ship freight. These companies help make choices concerning various intermodal methods (rail, long-haul truck, regional trucks, ships, etc.), routing and load sharing, to name a few strategies. Some also operate a fleet on a for-hire basis, and some do not.

Owner-operators – These are small business people who own, maintain and drive their own trucks. They can own between 1-5 units, mostly class 8 tractors used for long-haul for-hire trucking. From the survey results, they primarily purchase used tractors (average age 7 years) and drive them an average of 105,000 miles annually. About 70% of owner-operators are leased by the mile or percent of the load to larger carriers, mostly truckload firms. Leased owner-operators tend to have more security and get more benefits, such as truck leasing/purchasing options, using the company's fuel cards, training and load procurement. The rest are truly independent contractors often obtaining their freight via an association with large logistical firms like Land Star and Dart, or occasionally on their own via emerging internet based tools. As discussed in more detail in the findings section, they often own their own trailers and operate on a 1:1 trailer to tractor ratio, making trailer technologies more attractive for them as their trailers are constantly accumulating the miles and benefits.

Tractor OEMs – Truck Original Equipment Manufacturers are worldwide designers and builders of class 5-8 trucks and tractors. For North America they build units in NAFTA and retail and support their products through a channel of independent truck dealers. All truck OEMs also offer both commercially available and proprietary powertrains including engines, transmissions and axles. They also provide customer financing and a full menu of after the sale support. These firms engineer and integrate features onto the equipment they manufacture and must make tradeoff decisions to include items that help deliver efficiency and operations improvements for their end user, fleet customers. For some product features, OEMs control the design very tightly, including intellectual property rights and for others; they rely on suppliers for the technologies. Oftentimes, the OEMs are those who manage regulation compliance surrounding emissions and other requirements such as safety, etc. These companies have extensive engineering and product validation requirements and capabilities to ensure their and their suppliers' products meet the regulatory and customer expectations. They develop extensive understanding of how their customers use their products, have "voice" of the customer processes to define design requirements, design, prototype and test, demonstrate, manufacture and support the products.

Trailer OEMs – Trailer Original Equipment Manufacturers are primarily US-based builders of highway trailers used in commercial transportation. Products include dry freight vans, refrigerated vans, platform (flatbed) trailers, tanks, and intermodal container chassis. Like tractor OEMs they sell and support their products through an independent channel of OEM contracted trailer dealers. Compared to tractors OEMs, trailer OEMs have less employees, and their product development cycle times are much shorter.

Established Component Suppliers – These companies provide engines, transmissions, clutches, front and rear axles, suspensions, brakes systems, electrical components, tires, etc. to the truck and trailer OEMs. They promote components branded as their own but will also provide private label components for OEMs if desired. Most have been in the industry for most of the 100+ years it has existed and continually develop, build and sell products that meet customer expectations. They understand the intricacies of the business very well and have significant and deep relationships with the end user fleets and owner-operators. These relationships are useful as they promote efficient development of capable and robust products for their customers' customers. At times, this creates some tension with the tractor and trailer OEMs, but ultimately collaboration is strong as tractor and trailer builders work closely together to deliver the features integrated on the equipment for production.

New Technology Suppliers – As emissions requirements have expanded and fuel prices doubled in the last 6 years, new technologies have emerged from suppliers who are either startups or have not supplied the trucking industry in the past. These firms have emerged out of research institutions or vehicle markets such as the passenger car industry. Sometimes, companies in this group of suppliers are less knowledgeable of the trucking industry and oftentimes offer insights that diverge from views of the established manufacturers. For this study, a diverse group was selected, which included companies that specialize trailer aerodynamics, advanced engine controls, and operational telematics respectively.

These 12 groups, including the truck dealers, offer a comprehensive set of perspectives on the barriers to technology adoption. Each stakeholder group was asked common questions to more deeply understand all perspectives on a topic. In some cases, the supply chain interviewees were asked to provide answers from the end users perspective. That is, answer this question as you think your customer fleets would. For example, all were asked the required payback period in months that is acceptable for a fleet to move forward a purchase a technology. As mentioned earlier, companies and individuals selected for interviews and the owner-operators included in the survey, are often lead users. They typically understand and recognize the opportunities that fuel efficiency technologies can offer their businesses and have a perspective of those companies who are later adopters or non-adopters.

Data collection

The study ultimately included four different data collection tools. Table 2 summarizes the four main methods of in-person interviews, conference calls, focus groups, and online surveys. The methods were chosen to maximize the amount of information that could be gleaned from various industry stakeholders in an efficient manner. The project team interacted with individuals within larger firms via both face-to-face meetings and conference phone calls using interview templates. An online survey was developed to solicit responses from owner-operators. Example survey templates and interview questions can be found in Appendix B, C and D.

Table2. Summary of Data Methods

Data collection method	Targeted lead users	Details
In-person interview	• Large fleets • Established component suppliers	• Typically 1 -2 hours • 1-4 individuals from the companies • Many times conducted at Truck Shows/Events • Examples companies: Werner, Great Dane, Daimler, Volvo & Navistar
Conference call	• All other companies where it was impractical to meet in-person	• Typically 1 hour • Excellent attendance – none needed to be rescheduled. • 1-4 individuals • Examples companies: Cummins, Eaton, Frito Lay, Peterbilt, etc.
Focus group	• Truck Dealers with representatives from the American Truck Dealers Association.	• Lasted 1 hour • 6 Dealer Principles representing 5 of the 6 major NA truck brands • Large, competent dealers from all US regions
On-line survey	• Owner-operators and small companies (<10 trucks)	• Designed to take 30 minutes to complete • Let's Truck: 1,796 respondents • CSS: 96 respondents • In total, respondents own or operate 4,000 trucks
Truck show walk-arounds	• All stakeholders • Discussed preliminary findings with dozens of company representatives and owner-operators	• Conducted at the Technology and Maintenance Council Meeting in Nashville and the Mid American Truck Show in Louisville, March.

In-person interviews were desired for all companies other than the owner-operators as the team believed that this offered the most robust form of interviews and data collection. The project budget only allowed for in-person interviews at truck shows/events or while the interview team was visiting a particular company location for another purpose. Typically one member of the study team participated in these in-person sessions. This worked well as 42% of the company interviews were completed in-person. 80% of the targeted firms identified by the study team, agreed to participate in the interviews and all 29 interviews were conducted when scheduled. Interviewees titles included; Director of Operations and Maintenance, Director Vehicle Technologies, Fleet Engineer, Fleet Fuel Director, Founder and CEO, General Manager – Logistics Engineering and Development, Manager Advanced Engineering, President, Vice President Engineering, Product Manager, VP of Engineering and VP Sales. This approach generated input from individuals at the level of the company that has authority to make decisions in the areas of purchasing, development and integration of fuel efficiency technologies. Ultimately, the in-person interviews resulted in the most detailed and rich data. The same data collection templates were used for in-person and conference call interviews.

The conference calls were utilized for companies where the team believed input was essential and where an in-person interview was not practical. These calls were very efficient and attended by the key decision makers at the companies. It was clear that the participating companies were committed to providing the insights the team was interested in receiving. For these calls, one study team member was the interviewer and a second took detailed notes.

A focus group was only utilized for the truck dealers. The American Truck Dealers, a division ofthe National Automotive Dealers Association (NADA), was very helpful in organizing a focus group event at their annual meeting in February 2013 in Orlando, Florida. The dealers were very vocal and their insights important to adding an additional stakeholder perspective on the barriers to technology deployment.

The online survey approach was used to gain a better understanding of the owner-operators that haul freight. The team identified two groups that are knowledgeable on the technologies, their opportunities and barriers to adoption. Cascade Sierra Solutions finances retrofits for these small businesses, and Kevin Rutherford of *Let's Truck* has a membership via a satellite radio show and a business that offers tools for small business management. The high level of participation of these groups evidences a large interest in fuel efficiency and technology opportunities. Presumably, a large percentage of the surveys were completed from the cab of their trucks.

Post-survey analysis

After completing the in-person and teleconference interviews, the first step in the analysis was to compile notes from the sessions and transpose the responses onto the template survey forms, which were developed for each of the industry groups. In addition, direct quotes were recorded by the interviewees.

The online survey included 29 questions and was conducted between December 13, 2012 and February 11, 2013. In the first phase of online effort surveys were sent out a group of companies and individuals from a Cascade Sierra Solutions database, and 96 responses were received, of which 74% completed every question. The second phase of online surveys reached a much larger group of people due to a collaboration of Kevin Rutherford, who has a nationwide trucking focused radio program and consulting business, *Let's Truck*. From this group of *Let's Truck* listeners, 1,796 online surveys were returned, and 82% responded to every question. Responses were received from all over the country in both sets of respondents. The CSS survey responses are mapped in Figure 3.

Figure 4. CSS Survey Respondents' Location

The next step in the analysis was to distill the substantial data set into useable forms for further analysis. This was completed through completing various analysis documents such as key insights for each stakeholder group, a summary spreadsheet of all the answers to the common questions and common and disparate conclusions from stakeholder groups. This data was prepared for the team's subsequent step, which included identifying key themes that were evident across all of the industry groups. This exercise was primarily carried out during a late February 2013, two-day workshop for the entire project team, ICCT representatives, one of the expert panel and support from the Carbon War Room. The workshop began by reviewing all the available data collected and initial analysis performed, which led to the identification of an initial set of barriers. The team challenged these preliminary findings using various tools and made certain that they were truly what the interviewees and survey respondents shared. The team coalesced around the eventual key findings and documented the work in a "Preliminary Project Findings" document. The final deliverable of the workshop was to test these findings with four distinct groups, shown in Table 3 below.

Table 3. Preliminary Findings Reviews

Group	Attendees	Details
Expert Review Panel	• Nigel Clark, West Virginia University • Susan Mazur-Stommen, American Council for an Energy Efficient Economy • Bruce Stockton, Fleet Consultant	• 1 hour conference call with Susan on site • Group previously reviewed the survey design • Received significant questions and feedback
Industry	• Bill Kozek, General Manager, Peterbilt • Jim Williams, retired Executive, Navistar	• In person review with the team at the workshop • Industry provided perspective on the study findings
EPA	• Various Environmental Protection Agency personnel	• 1 hour conference call at the end of the workshop • Participants from Washington, DC and Ann Arbor • Robust Q&A
NHTSA	• Various National Highway Traffic Safety Administration personnel	• 1 hour conference call within one week of the workshop • Robust Q&A

As is described in detail in the following section, five primary barriers to the adoption of fuel-saving technologies emerged in the analysis: lack of credible information, uncertainty with respect to payback time, insufficient capital, unacceptable reliability, and lack of commercial availability.

After identifying the five primary barriers, the next step in the process involved analyzing how the responses varied within each of the industry groups. Table 4 provides a high-level qualitative summary of the degree of consensus for each of the interview groups across the five barrier categories. In general, there was a high level of consensus with respect to the lack of credible information and uncertain payback as critical barriers. The significance of the access to capital was a larger issue with the smaller end users, while the larger size fleets including the private and lease fleets said they could get the capital with sufficient confidence in the payback analysis. End users were more critical of the reliability of new features, while the supply chain had a moderate agreement. The fleets and suppliers had a high degree of consensus concerning the lack of availability barrier, while the integrators (tractor and trailer OEMs) somewhat concurred. Each of these five barriers is discussed in the detail in the following section.

Table 4. Qualitative Summary of Interview and Survey Responses

Survey Group	Number of interviews or surveys	Degree of consensus across primary barrier areas				
		Credible information	Uncertain payback	Insufficient capital	Unacceptable reliability	Lack of availability
Large fleets	5	G	G	R	G	G
Medium fleets	1	G	G	G	G	G
Used fleets	2	G	G	G	G	G
Retail-Private fleets	4	G	G	R	G	G
Lease and Rental fleets	1	G	G	R	G	G
Owner-operators	1,892	G	G	G	G	Y
Tractor OEMs	4	G	G	Y	Y	Y
Trailer OEMs	2	G	G	Y	Y	Y
Established manufacturers	3	G	G	Y	Y	G
New technology suppliers	5	G	G	G	Y	G
Shippers & Logistics	2	G	G	N/A	Y	N/A

Green: high degree of consensus; yellow: moderate consensus; red: low degree of consensus

III. Findings

This section reports on findings of the analysis of the input gathered from the 15 one-hour end user company interviews, 6 large truck and trailer manufacturers, 14 supply chain companies and 1,892 owner-operators via internet surveys. Based on the process identified in the previous section for filtering results from the various survey methods, the team then mapped key answer analytics and interviewee quotes to better explain each of the barriers.

Lack of credible information about the total cost of ownership and reliability of technologies in early stages of deployment as well as a deficiency in information sharing across the industry as technologies mature were identified as overriding barriers to greater rates of adoption. Uncertainty around the payback for an investment in a technology and the lack of access to capital to actually make the purchase were identified as barriers that are highly interrelated. Insufficient reliability of the product in real-world operations and the lack of availability of the features from a majority of the tractor/trailer OEMs were also barriers identified by the team based on responses provided by various end user stakeholders. Each barrier is addressed in this section of the report by describing the barrier, providing representative stakeholder quotes that capture the essence of the issue, and analyzing the extent or agreement or disagreement both within each industry group and across all of the stakeholder categories.

Uncertain Payback Time

Based on responses from end user fleets, many technologies do not seem to have acceptably short payback for adoption.

"It's all about our payback calculation!" – multiple end users and supply chain companies.

Payback time, as defined in this study, is the time it takes for the cumulative fuel savings of a technology to offset the additional capital and operating expenses presented by that technology. Across all of the industry groups, there was consensus that payback time is the most important economic calculation in guiding the decision making process of whether or not to investment in a fuel-saving technology.

One of the key boundary conditions in a payback analysis is the expected time that a fleet or individual intends to own a truck. All of the interview responses confirmed previous research findings and anecdotal evidence that trucking fleets require payback times that are shorter than their ownership cycles so that the technology can not only offset the additional capital investment but also provide a return on investment. As discussed in more detail in the Capital Cost section below, fuel-saving technologies are often not valued in secondary markets, which makes it that much more important that technologies pay for themselves well within the time that a fleet owns a tractor or trailer.

As reported by the end user fleets in this study, truck ownership cycles vary widely, as shown in Figure 5. Private fleets tend to keep their trucks longer, while large for-hire carriers tend to sell their trucks after four to six years to secondary users, which are referred to “used truck fleets” in this study. The shortest reported trade cycle was four years, and most of the for-hire fleets stated that they are trying to lower their truck ownership times back to four years after extending ownership times during the recession to 5, 6, and 7 years. ACT Research reports that the average truck age increased from around 6 to about 7 years as a result of the recession (Vieth, Kenny, personal communication, April 30, 2013). According to interview responses from for-hire fleets, their trucks average about 120,000 miles per year, and these fleets tend to buy new and sell trucks when the maintenance costs reach an unacceptable level at about 500,000 to 700,000 miles. The trucks then typically move into lower mileage routes operated by smaller fleets, owner-operators, and agricultural operators for rest of their life.

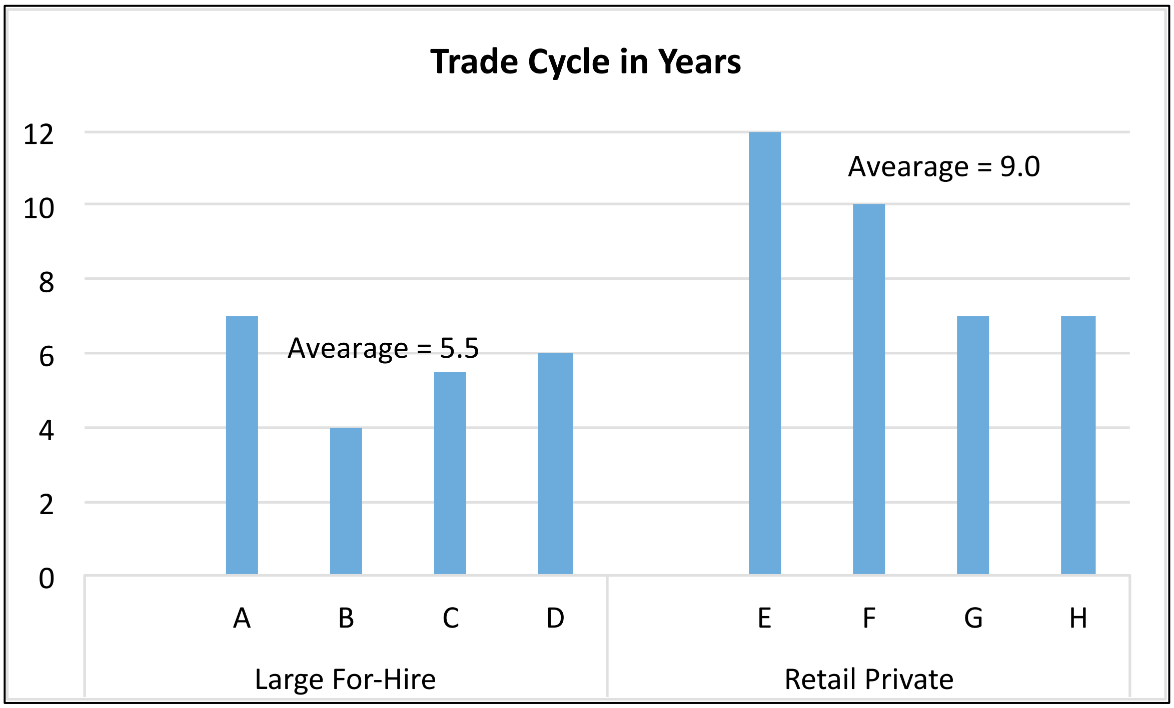

Figure 5. Tractor Trade Cycles

In all of the interviews, the team received responses on the acceptable payback period, and for owner-operators, this data was collected via online surveys and is summarized in Figure 6. Large, medium and lease/rental fleets stated that a payback time between 12 and 24 months is required, while private fleets reported that a longer payback period – 24 to 36 months or more – is acceptable. Of all of the industry groups, the distribution of responses about required payback times was most varied for the owner-operators. Though over 80% of owner-operators reported an ideal payback time of 2 years or less, the respondents reported payback time preferences of up to 3 or more years. For retrofit technologies, payback periods of less than 24 months were deemed reasonable by 92% of the owner-operator respondents.

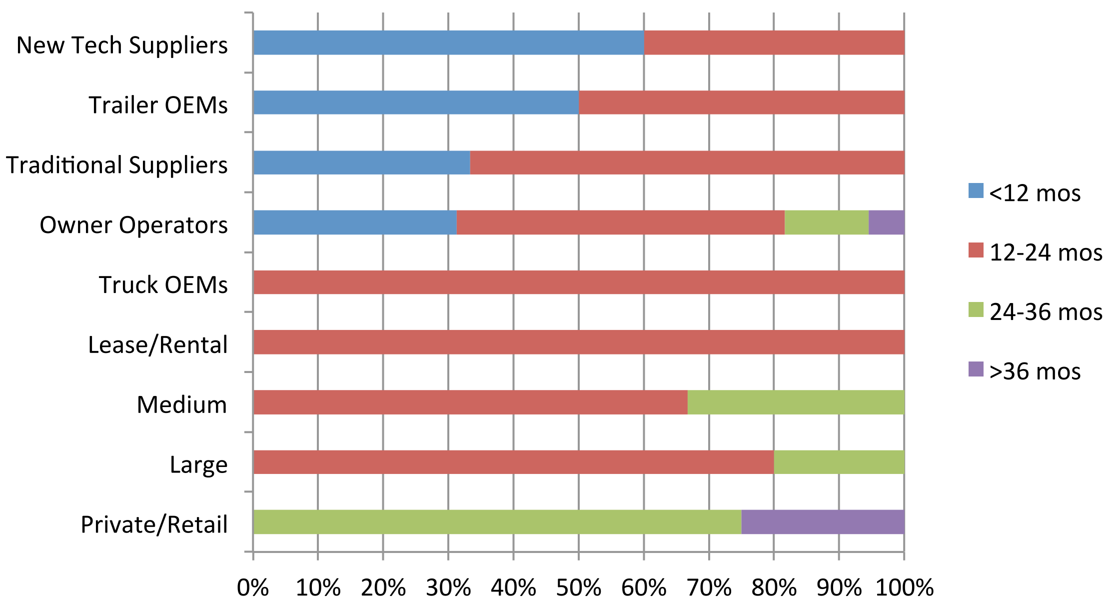

Figure 6. Acceptable Payback for Technologies

The responses from end user fleets are contrasted somewhat by the replies from the new technology suppliers and tractor and trailer OEMs. The technology suppliers and OEMs were asked to take the perspective of an end user trucking fleet, and the reported payback time requirements from these manufacturer groups was, on average, shorter than those reported by the fleets. This seems to imply that manufacturers are, in general, more conservative in terms of their belief as to what payback times the fleets will accept. This view that end users require very short payback times (less than a year in roughly half of the manufacturer responses) likely has important implications on the decision-making process about product development activities by the suppliers.

A truck OEM General Manager summarized the acceptable payback period for long-haul trucking as follows: “The customer sees [payback time] as one-half their trade cycle, which means 18 to 24 months on trucks kept about 4 years before trade time." Based on interviewee responses about their own business models and attitudes about the trucking sector as a whole, payback times of roughly one-half of the truck ownership cycle seem to be the industry norm. Given this rule-of-thumb, it follows that large for-hire carriers require a more rapid return on investment due to shorter ownership cycles, while private fleets allow for longer payback periods, as they tend to operate the equipment for more years. However, the interviews revealed that there are sometimes other non-monetary factors such as "green image" or shipper requirements, which may cause a fleet to extend the payback period to justify purchasing the technology.

While the reported preference for payback time was generally in the range of 12-24 months, the questions about payback resulted in a variety of responses. For example, some large fleets stated:

- "[The payback requirement is] 36 months or less, maximum payback is 48 months but varies by equipment type. Trailer trade cycle is about 10 years" - Vice President
- "Nothing's set, but usually [the payback requirement is] 24 months, also want 15% return on capital." – Vice President, Purchasing
- "[The payback requirement is] 18 months on tractors based on 3-4 year trade cycle and 36 months on trailers based on our 7 year trade cycle. Local dealer gives good residuals so that drives shorter truck trade cycles and trailers must meet new EPA and CARB requirements." - Vice President
- "[The payback requirement is] 24 months. [We] can usually calculate maintenance and reliability gains." - Fleet Fuel Director
- "We retrofit if we believe there is enough life left for payback. We trade our trucks at 4 years and retrofits are generally become challenging. " - Vice President

Medium and used Fleets had similar responses, with interesting caveats:

- "[We select a technology] if the return on investment is 2 years or less, and the product has low maintenance." – Chief Executive Officer
- "[We select a technology] if return on investment is 2 years or less, we might add to our application." - Director of Operations and Maintenance
- "[To select a technology] we would need to have a tested 3-4% fuel savings with a quick ROI (12 months or less) to spend resources on new technology." – Vice President of Operations

As stated above, responses from private fleets clearly reflected their longer trade cycles:

- "[The payback requirement is] 25% ROI or three-and-a-half years if it's with a new truck purchase." - Fleet Engineer
- "[We] keep tractors about 12 years and trailers 15+." - Director, Engineering
- "As always, payback is the big thing. Since we keep trucks so long we do more retrofits than most carriers with shorter trade cycles. " - Fleet Engineer

- "Due to a longer trade cycle (10 years), we will consider doing more retrofits than a lot of larger long-haul carriers. " - Fleet Engineer

Truck OEMs tended to expect short payback periods:

- "It is all about payback. Shorter the better no matter how much it costs." - Product Manager
- "Internally, [we] use 18 months to justify adding the feature to our products." - Product Manager
- "If the fuel saving technology pays back for the customer and for our investment. 1-2 years is the most common payback period." - Marketing Manager
- "[We aim to provide] payback that meets the 1-2 year customer criteria. Many fuel-saving technologies can provide [this] payback." - Marketing Manager
- "[An OEM's decisions to offer or improve a fuel-saving technology is] based on cost/benefit (tooling and fixed costs) versus ability to collect [a higher sale] price." - Director, On-Highway Vehicle Strategy
- "Fuel savings [i.e. fuel-saving technologies] are targeted for the on-highway long-haul customers more so than for lower speed, lower mileage operations. Criteria is 1-2 year payback on the fuel savings." - Marketing Manager

Some major component manufacturers stated:

- "We think fleets want 12 to 18 months." - Strategic Business Segment Manager
- "18 months [for the payback time requirement] is typical in over-the-road tractor-trailers." - Director, Vehicle Technologies and Innovation

Finally, the General Sales Manager of a trailer OEM asserted: "Trailer life is now 10 to 12 years, up from 8 a few years ago. This should help adoption [of fuel-saving technologies] as the fleet has more time to gain the payback."

A number of end users were asked how the payback calculations reflected their unique business models and duty cycles. Technologies for tractor-trailers vary widely in terms of additional capital costs and operating expenses, and fuel savings benefits are often intimately linked to operating characteristics such as vehicle speed, payload, grade, and ambient conditions, which can be different from fleet-to-fleet and vary based on geographic location. All of the fleets were asked what elements are included in their payback calculations. The answers ranged significantly, showing that some fleets are more detailed and thorough in their analyses. A few fleets mentioned categories of payback items in terms of "hard costs", those that are easily measured and directly attributable to the technology. They include such items as the fuel savings, upfront cost of the device, maintenance, infrastructure, and training. Second are what some called "soft costs", which are costs that are difficult to estimate and generally not included in the payback calculation. Some examples of soft costs include impacts to resale value, reliability and driver attraction and retention. Finally, a fleet might include directional "pluses/minuses" that become bullet points in the analysis where costs cannot be defined. These include sustainability initiatives, *green* imaging, safety impacts, and shipper requirements. As described by some of the larger fleets in response to the payback questions, when a fleet manager conducts the payback analysis and provides the formal proposal to their finance organization, many of the soft costs and plus/minuses are removed from the proposal.

Most technology suppliers develop payback calculators, share them with their potential customers, and put them on their websites. Tractor and trailer OEMs use these tools and also develop their own calculators to evaluate various technology solutions for inclusion in their product development pipelines. Those more promising technologies get a higher priority in their engineering plans. Finally, fleets perform payback calculations in order to inform the decision of whether to purchase the technology and what supplier or OEM from which to acquire the technology. In describing the challenge of calculating payback, a Vice President of one of the large fleet carriers stated that, "Suppliers do not provide all the elements of a strong payback analysis and the fleets are maybe too conservative in the calculations, due to being burned in the past." He went on to describe an actual situation where they were studying a potential safety feature, an anti-collision product that alerts the driver via radar of close proximity hazards near the truck. During a significant field trial of dozens of vehicles with and without the device, where the company was using telematics to collect data, a field engineer noticed a sizeable savings in fuel as the result of the operators driving the trucks more cautiously. This fleet decided not to include these fuel savings as a benefit to the safety feature, as this was not a fuel efficiency project, but a safety one, and those fuel savings were not included in the payback. This provides an example of the conservative nature of these calculations.

As a result of 1) the difficulty of testing the real-world performance of technologies and 2) a feeling of the fleets that technology suppliers generally oversell the benefits and minimize the challenges, it is rational that fleets' payback analyses tend to be conservative in nature. It is clear that there does not seem to be any standardized, universally used methods in these calculations throughout the industry, which is likely due to the highly diverse nature of the trucking industry and the desire of fleet managers and owner-operators to utilize payback calculations that best represent their unique conditions.

Many of these technologies can be retrofitted onto trucks already in service. This can be a good strategy for fleets to take advantage of the benefits, if there is sufficient time in the life of their equipment ownership for the technology to payback. As shown earlier, retail private fleets shared a greater interest in retrofitting due to their longer ownership period. Fleets reported using the same payback calculation and decision-making process for retrofit technologies as technologies included on new tractors or trailers.

In summary, this study suggests that all fleets make decisions to buy new technologies using a payback calculation, and the manufacturing industry also uses payback time as a key metric in determining what products to develop and bring to market. Though the responses varied, the stated expectation for payback time was typically half of the truck ownership cycle. Interview responses showed that large for-hire fleets generally purchase new trucks and operate them four to six years, which translates to a payback time expectation of two years so that in the final two or more years of truck ownership, the fleet can see a return on investment. Truck and trailer OEMs and component suppliers customarily use two years or less as the benchmark for payback time, which signals that the requirements of the fleets with the shortest ownership *cycles are driving the product development process for the entire industry. Payback calculations seem to vary in terms of the parameters that are included in the calculation and tend to be rather conservative to reflect the uncertainty surrounding thefuel savings, reliability, durability, and additional maintenance or operations impacts that are associated with a technology.*

Capital Cost

Often, there is a lack of capital for purchasing fuel-saving new technologies.

"Due to the high costs of the trucks now, I simply cannot get the capital for these features."
– Vice President of Operations, a medium-sized fleet

Many end users expressed that the high cost of new trucks is a challenge for purchasing many of these new, additional features. At times, there is an acceptable payback period on a technology, but fleets still choose not to buy them due to their high upfront cost. Based on responses from all of the end user stakeholder groups, the overall cost of the tractor has increased dramatically over the last six years. Many shared that the overall costs of new trucks and the financial constraints since the recession have limited the availability of capital for many actions the fleets would like to take.

Fleets and tractor OEMs confirmed that new tractor costs are up significantly in the past years due to some of the following factors. The costs shown below are an aggregation of comments made by many interviewees.

- In total, engine modificaitons and aftertreatment systems that were required to meet crtieria pollutant emissions regulations in 2002, 2007, and 2010 have increased the cost of trucks on average about $15,000 combined
- Driver ammenity features added to trucks to attract and retain operators during a signficant industry shortage, safety features, and material cost increases have added another $10,000 on average.

From the interview responses, the $90,000 to $100,000 price for long-haul tractors with sleeper cabs in 2006 now costs on average between $115,000 and $135,000, which is roughly a 20-30% increase in 7 years. Fuel-saving technologies generally add costs to the new truck and increase the amount of money the purchaser needs to justify and in many cases finance.

The Vice President of Operations of a medium fleet shared that, "Regulations have mandated a generous amount of capital to be spent meeting regulations, particularly in California." An owner-operator specifically stated that "many of us believe that air quality regulation compliance restricted our investments in fuel-saving technologies." They continued, "We would be more apt to work on incorporating fuel saving technologies if the capital was available." The fleets seem to not rely on or even expect federal or state incentives to help pay for the devices. Most shared that they pursue incentives if they exist, but rarely use any expectation of incentives in their payback calculations. Therefore, they do not typically factor incentives into their purchase decision. This study did not specifically ask to what degree the financing mechanisms in existence today effectively support technology adoption. Future research into the areas of unique funding mechanisms that are being implemented in other cleantech ventures such as solar and wind can be conducted to more fully understand the opportunity for them to reduce this barrier in the trucking industry.

The President of a new technology supplier expressed a somewhat opposing view stating that: "Access to capital does not seem to be an issue, for products with strong payback." This vendor believes that the capital would become available if the cost of his devices and their fuel savings benefits were carefully considered.

As discussed in the previous section on payback time, a key factor in the financial calculation is the resale value of the tractor. Oftentimes, a new technology, even when appropriate for the second owner, does not have much (or any) value in the used truck market until there is more widespread adoption of the technology. The Director of On-Highway Vehicle Strategyof a truck OEM stated that "The increase in EPA mandated costs makes everything –cost of finance, maintenance, purchase price, service and driver training – more expensive and none of this added cost will increase the resale value of the truck. New technologies take a long time to gain confidence and alter the resale value." In the focus group of truck dealers, this sentiment was reiterated: "new technologies take a long time to gain confidence and impact the resale value."

This study asked all interviewees what factors most influence their specifications for new equipment. Figure 7 shows the results of this question and demonstrates the high value fuel economy has on new truck specifications. Along with fuel economy, reliability, maintenance and durability have an equally high influence on purchasing specifications. Many interviewees stated that fuel economy would have been a much lower priority if surveyed even just five years ago. Resale value is somewhat important, likely again driven by the varying ownership life.

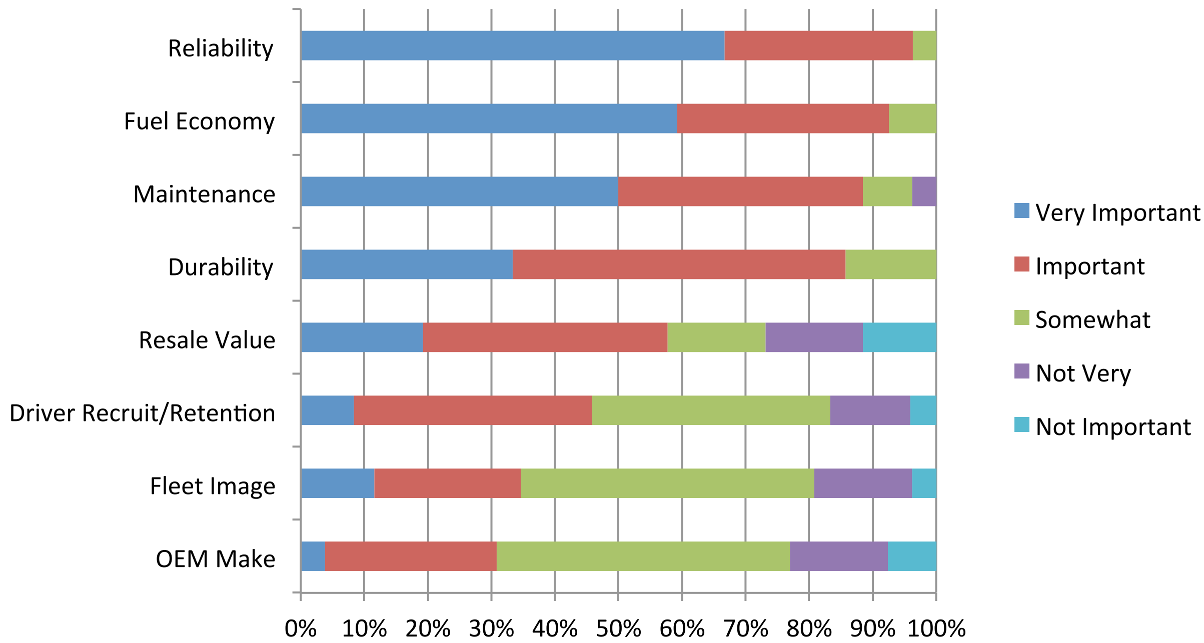

Figure 7. Importance of Factors Influencing Specifications

Specific to the question of resale value, the four private fleets rated the influence of resale as not very or not important at all, while tractor and trailer manufacturers and suppliers rated it somewhat important, probably averaging their implicit understanding of the requirements of all the fleets. Most interesting in the analysis was the greatly divergent responses of the five for-hire fleets. Their responses varied from very important to not important, as shown in Figure 8 below. When asked follow-up questions, it appears that the fleets who value resale as not important or not very important see fuel economy as such a key new requirement that they are deciding to not allow the resale situation to be a major influence against adoption of these technologies. They stated that they will keep the trucks longer if they are delivering the MPG savings rather than sell them if the used truck market does not value that specification. A fleet Vice President shared, "Since fuel got about $2 per gallon, we track the cost per mile down to 1/10 of an MPG, and it's more about operating costs than resale."

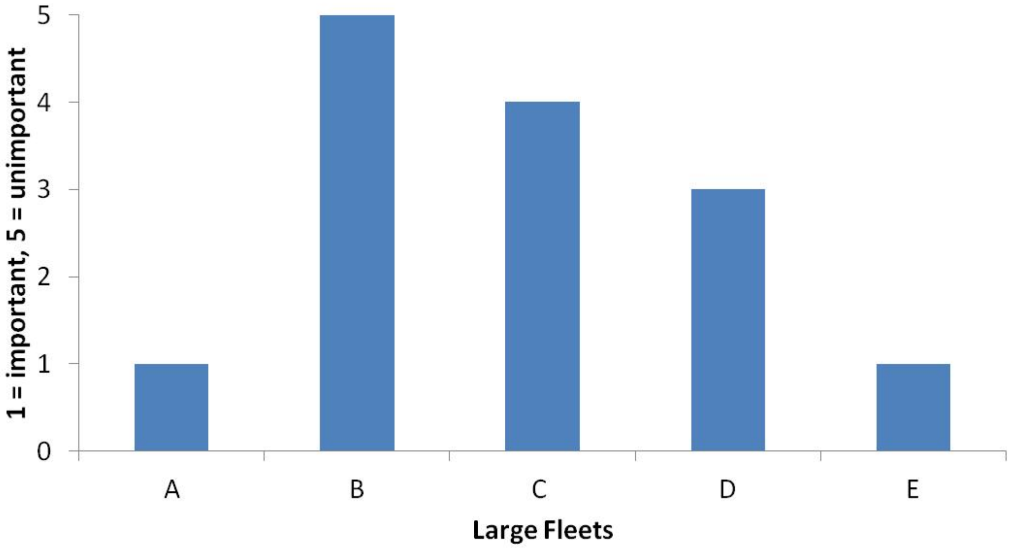

Figure 8. Value of Resale to each Company

In summary, some fleets shared that access to capital is an issue, even if the fleet has confidence that a fuel-saving technology delivers a payback for their operations. New equipment costs (adjusted for inflation) have increased significantly over the past 10 years, and the money a fleet can spend on fuel-saving technologies compete against driver amenities to better attract and retain drivers and other new technologies to improve safety, communications and routing.

Credible Information

It can be very difficult to predict the performance of technologies for the trucking sector. Many duty cycles over vastly different geographic regions and environmental conditions and diverse business models of fleets exist in the North American trucking industry. The Study team found that the lack of credible information occurred in two phases over a technology's development, demonstration, and adoption. First, in verifying that the technology is valid in specific applications and then later, in sharing that information throughout the industry in order to maximize the benefit of the technology across the vocations appropriate for it. Figure 9 shows a typical new product adoption curve, based on the work of Everett Rogers in Diffusion of Innovations (Rogers 1962, 150), in which he broke down the customer uptake into groups: innovators, early adopters, early and late majority and laggards. The study team added the two phases of credible information barriers to the chart.

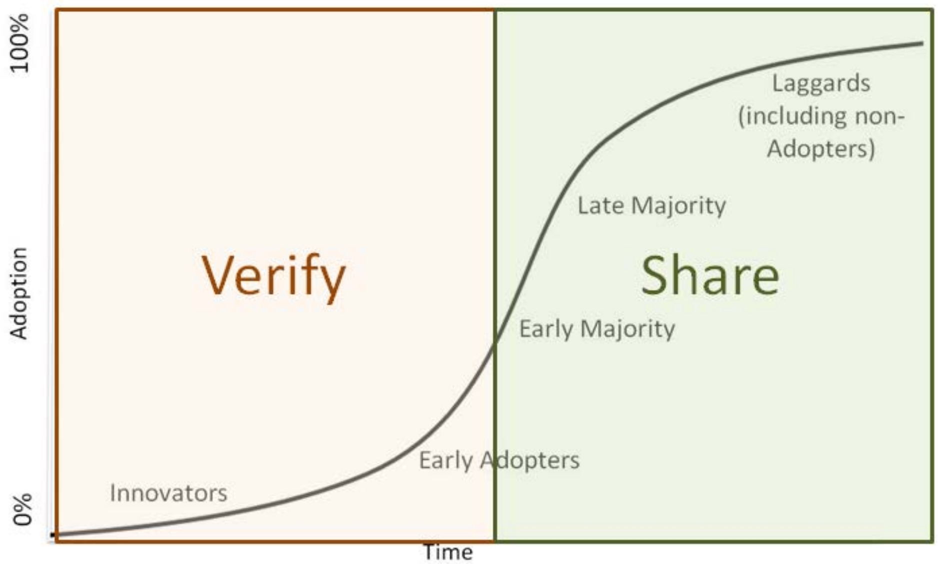

Figure 9. Information across Adoption Cycle

Credible Information Verifying (Early)

In many instances, end users have difficulty obtaining data on new technologies in order to make informed purchase decisions.

"We only buy what we test – only trust ourselves" – a large fleet Vice President

Many end users stated that the inability to verify performance claims of manufacturer's devices was preventing them from adopting efficiency technologies. The vast diversity of variables such as truck make and model, duty cycles, business models, geography, and weather makes fleets and owner-operators hesitant to believe that the performance results from manufacturer's tests are applicable to their own operations. Fleets want confidence that the technology delivers benefits, so they generally test technologies in their own applications after reviewing the public and manufacturer-supplied data available to them. Table 5 offers answer summaries to some questions asked with respect to how often fleets require third-party tests from manufacturers and when they conduct their own testing. In the early stages of a technology's deployment, there is a limited amount of information, and fleets tend to default to testing themselves. The Director of Vehicle Technologies and Innovation for a well-established component supplier stated that, "Fleets have a general mistrust of standardized drive cycles and the associated test results, as they will not reflect the performance of the technologies in their operations." A Product Manager for a truck OEM, somewhat frustrated with this sentiment of fleets, stated, "[A fleet's belief that a technology's fuel savings results will be different if applied in their operations] oftentimes leads to a distrust of the data provided by suppliers and OEMs. Budget and time to conduct their own testing is definitely a barrier to early adoption of technologies. Our industry is a 'show me' one." Nevertheless, manufacturers continue to demonstrate the performance of their products using standardized test protocols to help the fleets understand how the technologies deliver benefits in the real world. As the Vice President of Engineering for one trailer OEM stated: "We go from concept to design to validation testing to production. Testing usually takes 3-6 months. We use a wind tunnel to test and measure effectiveness of aerodynamic products and the Bosch test track to internally test our products for durability and to also validate fuel savings data. Many features we offer are customer requested."

Table 5. Interview Answers to Testing Questions

Do you require testing by a 3rd party?	Yes	No	Some-times	
	39%	26%	35%	
If yes, what % does the supplier pay?	All	Half		
	80%	20%		
Do you require a trial in your fleet?	Almost all the time	Most of the time	Some-times	Rarely
	26%	52%	5%	0%

The team asked all interviewees how the end users valued information from various sources, as shown in Figure 10 below. By a large margin, the fleets value their own testing on a technology and use other sources to help validate it. Other fleets' input, attained either directly or at industry events such as the Technology and Maintenance Council's (TMC) Annual Meeting and Transportation Technology Exhibition, ranked higher than information from manufacturers, OEMs and the EPA Smart Way Program. As a medium fleet CEO shared, "We are keeping abreast of what other larger fleets are doing and attend most TMC meetings and seminars on new technologies and alternative fuel advancements."

One major component manufacturer's Head Engineer for On-Highway Products uses a collaborative model to test its products: "Internally we develop and design product features and test them for validation. We have our own test truck drivers whose 'truck driver' input is valuable to us. We do trial runs with larger fleet customers for further validation. We then take the product to the truck OEM to get their buy-in. This process can be slow, especially if it involves hardware changes or chassis reconfiguration of the truck. If we only need to make software changes this process is much easier as OEMs give us free reign on the 'black box' in most cases. One example of a 1-1.5% fuel savings change we learned by making our air compressor naturally aspirated has not yet been accepted by OEMs."

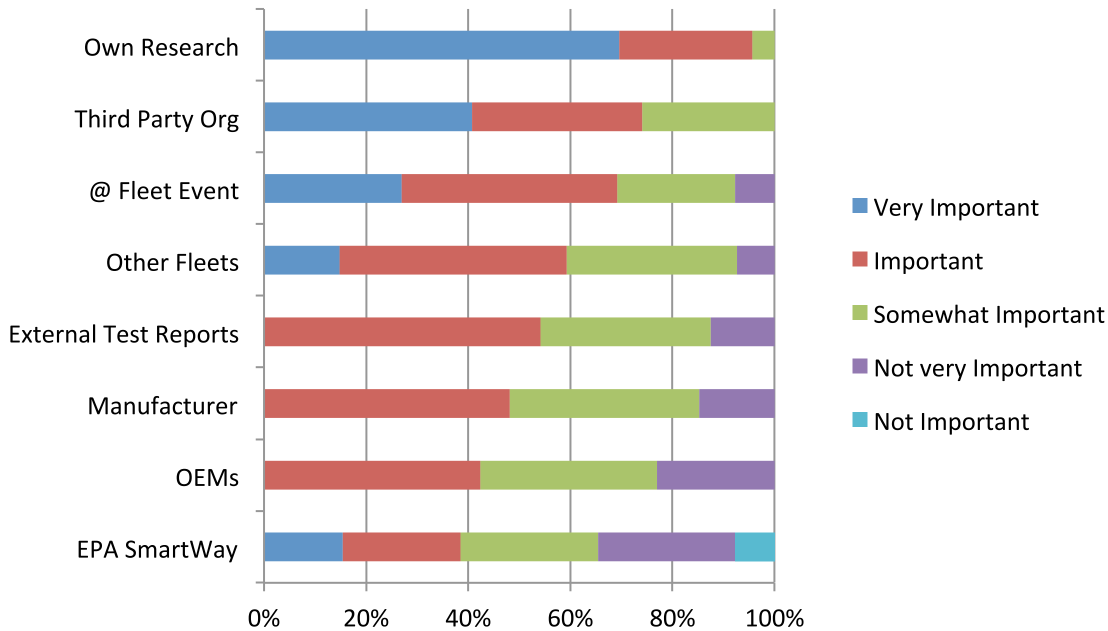

Figure 10. Value of Various Information Sources

The President and CEO of a large fleet stated that, “Data is difficult to acquire and researching other data is too time consuming; therefore, we only work on big opportunities.” The Director of Engineering of a private fleet shared that, “Occasionally we combine tests, for example, mud flaps and wheel covers with a tire test, but almost never do testing with other fleets.” Early adopter fleets are to be commended for their testing efforts, as they are generally thorough in their data collection. The Vice President of Operations of a medium sized fleet shared what they see with these early adopter fleets: “Some fleets have robust testing methodologies and procedures in place with strong collection of data. They have specific fuel efficiency routes, dedicated trucks and trailers, test drivers, etc. and bring this data back to investment teams within the fleet for decision making.” But, rarely is this data shared in a useable manner with other fleets or the manufacturers. Another important factor was shared with the team by a component supplier’s Head Engineer of Engineering for On-Highway Products: “Fleets who gain fuel efficiency at times will keep the data ‘close to their vest’ for the first year before sharing. Then, they begin to share in order to help get more scale for the feature and then hopefully, commensurate higher quality and lower cost.”

Other large fleets offered their perspectives on the need to collect data specific to their operations for emerging technologies:

- "Almost all the technologies adapted to the fleet have been the result of testing by the manufacturer on our fleet in our different applications." - President and CEO
- "First insure that the component supplier or OEM has run their own SAE type test and, if so, then ask for the data ('devil in the details'). Then, if it looks viable, we will discuss how it impacts drivers, maintenance, weight, and reliability. Then if all good then we'll test them to validate, and then make a proposal to our leaders to purchase. We use a local 40-50 mile SAE Type 2 (#1321) real-world road test to validate results with our own specs and configurations." Vice President of Purchasing
- "We study various technologies and test and adopt those that prove they will improve fuel efficiency. We require suppliers perform SAE testing before bringing any technology to us to evaluate." (Vice President
- "Suppliers are proactive in contacting us with new ideas due to our size and visibility. We learn of new ideas at conferences and trade shows. We have a person with title of MPG Director and a MPG committee who meet twice monthly. We'll look at supplier test results but will 100% test ourselves any new technology prior to implementation. Our testing is SAE Type 2 and SAE Type 4 first, then if results look good, we'll put into our own ROI model for analysis and then discuss with fuel committee and others for approval and funding." - Fleet Fuel Director
- On valuing suppliers' support with test results, a President and CEO, stated "Almost all the technologies adapted to the fleet have been the result of testing by the manufacturer on our fleet in our different applications."

Other stakeholders commented as follows:

- "Not so much that fleets think we are trying to lie or over-estimate the benefits of a technology, but more in that we were not testing it in the same usage profile as the fleets operate in." - Product Manager at a truck OEM
- "Fleets that have good relationships with OEMs really value OEM data. OEMs would want that [fleet] data too; they don't have unlimited resources to do it all themselves." - Director, On-Highway Vehicle Strategy, truck OEM
- "We have a few dedicated engineers whose sole job is to evaluate and work with these manufacturers." - Director, Engineering at a private/retail fleet
- On the suppliers' need for help from the fleets: "We conduct our own tests and depend on fleets to assist." - Founder and CEO of a *New Technology* supplier

From Figure 11, the research of third-party organizations was valued just after the fleets own research, but fleets and the supply chain stated that no trusted option currently exists. The EPA Smart Way is a voluntary testing and certification program that provides free information to fleets, shippers, and other interested parties, but its value was generally rated quite low. However, a few interviewees did rate it as very important. Those rating it somewhat or not important shared concerns that the program is managed by a regulatory entity of the federal government with a lack of industry input into its strategy and tactics, and there are limited resources for doing sufficient analysis in order to verify technologies.

The vast number of test protocols that exist throughout the industry contributes to this credible information dilemma, as it is often challenging to compare the results. The Founder and CEO of a new technology provider stated, "Everyone seems to modify the test protocols as they see best. Much could be gained by deciding on one or a few protocols and using it across the industry. Make it statistically important and encourage or demand its use." Another important issue is that sometimes technologies are tested and implemented in packages, making it difficult to know which one is actually contributing to the results that a given fleet may be experiencing.

Other direct comments concerning independent experience and data included:

- "We value SAE Type 2 vehicle, 'real world' testing results [given that the test matches this fleet's application and unit configuration]. We give this type of testing more validity than OEM, supplier or other customer testimonials. I believe in Ronald Reagan's 'trust but verify' philosophy. I would value a true unbiased third-party test as long as they can evaluate my like spec and configuration…and there's a limit to how much one party can do." - Vice President, Large Fleet
- A General Manager at a truck OEM shared the comprehensive nature of their validation efforts: "We use internal and external tests with customers and third parties as well as test on our own proving grounds."
- "We conduct a lot of bench testing to have confidence in our numbers then use tools to predict their performance on trucks for our customers. We conduct and support SAE tests by fleets and OEMs." - Strategic Business Segment Manager, Components Supplier
- "[We] need real SAE type testing to get [fleets'] attention, but fleets say that they still need 3 sets tested over 6 months to evaluate. But if they see a big enough MPG early, then they may not need all 6 months." - Founder and CEO, New Technology Supplier
- Another new technology supplier commented, "We tested our systems for durability and used extensive early fleet trials to fine tune mounting, etc. One trailer OEM completed a 6 month shaker test, which seemed very long, but after it was successful, it helped us convince fleets of the robust design." - President
- "I believe that industry is underutilizing information from owner-operators using their own truck and trailer to test and report fuel savings technologies. Unlike the major fleets that do not use dedicated drivers (many have over 100% turnover annually) on the same equipment, owner-operators or smaller fleets use the same driver on the same truck pulling the same trailer….so more accurate data can be obtained…plus, since they're paying for their own fuel they embrace these technologies." - President, New Technology Supplier
- "Testing – most fleets want to test technologies with their own specs and operating environment but we are concerned sometimes they are not doing enough units for a viable sample size." - General Manager at a truck OEM
- "The decision to implement a technology always depends on your starting point. Examples – tire inflation system did not improve MPG much because we feel we already have a good tire

maintenance program and drivers are educated on how to check air pressure." – Vice President of Purchasing at a large fleet

- And finally, a new technology supplier's founder and CEO described their third-party test protocol, pointing out the value of involving owner-operators, "We do scale model testing in wind tunnels where we can rotate the tractor-trailer to simulate angle of wind. We use third-party testing (the Truck Research Center in Ohio) for SAE Type 2 test track testing of prototypes installed on rigs. We use owner-operators for further real life validation because they drive more miles, have a 1-to-1 tractor-trailer ratio and keep better records than random fleet drivers."

In summary, verifying performance in the early stages of technology deployment is challenging, duplicated testing efforts by multiple fleets and manufacturers is commonplace, and data is not often shared or trusted by outside parties. This often causes confusion with fleets that are interested in adopting a technology and delays manufacturers as they verify anew technology's performance. Fleets seem to understand that it is difficult to stay abreast of all the technologies being developed by testing themselves, but they rarely have full confidence in external results.

Credible Information Sharing (Later)

As early and late majority users adopt a technology, personal experiences (via word-of-mouth) seem to be the primary method for sharing of information about a technology's fuel savings, reliability, maintenance impacts, and overall impressions.

"If we can't understand it, we can't value it." – an owner- operator

As discussed in the previous section, from large fleets to small owner-operators, the industry overwhelmingly reported that they rely almost exclusively on their own experience and in other end users' data when making a decision to adopt new fuel efficiency technologies.

Smaller fleets generally do not have the resources to investigate and test the new technologies in their operations, and many fleets of all types have decided to be followers in implementing these technologies. However, this does not at all imply that all innovators and early adopters are large fleets. One large fleet President and CEO, likely a late majority or laggard adopter, stated, "We sometimes wait too long. We must rely on other fleet's data for us to move forward, but we are skeptical of their understanding of fuel efficiency. They may know maintenance and reliability costs well, but fuel efficiency is hard to measure and that data can be dubious. We do use data from large, valid carriers that we trust."

End users were asked to select the primary reason they did not adopt available technologies, and Figure 11 shows the top six reasons. The top three reasons were: 1) inadequate product support (i.e. services such as new product training and after-sale support); 2) manufacturers' data showed technology was not appropriate; and 3) that the technologies were not relevant to their operations. Each of these issues are valid reasons, assuming that credible and sufficient data are included in the decision making process. The next three reasons were: 1) there was no outside validation; 2) testing was inadequate; and 3) the data was not convincing. These three reasons suggest that the fleet believes in the technology but has inadequate information to make a decision to purchase or retrofit a technology on their trucks and/or trailers. These responses indicate that many fleets – even those who are very interested in adopting new technologies – do not have enough information in their decision-making processes.

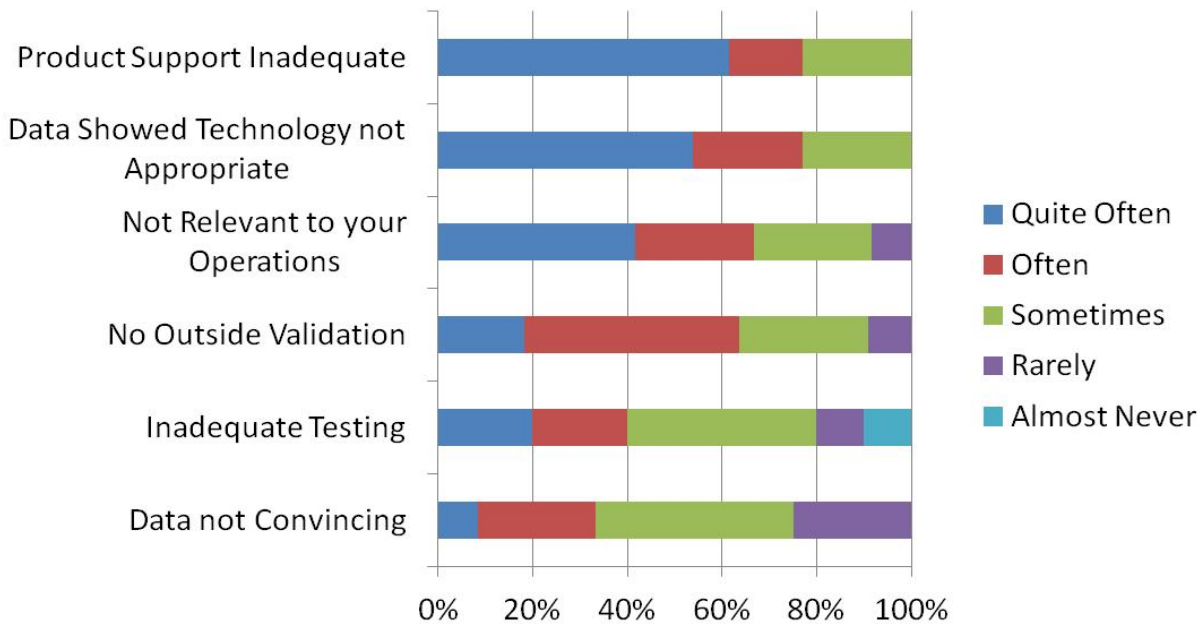

Figure 11. Top Reasons Not to Purchase

Uncertainty concerning the technology continues, and this may encourage lack of appropriate investment in the firms offering the technologies, which, in turn, results in delays in cost reductions due to increasing production and economies of scale. Another large issue is the maintenance of both sets of technologies by manufacturers and truck and trailer builders who need to maintain both in their product portfolio and engineering and manufacturing plans. Engineering changes, such as emissions regulation changes and new cab introductions, must accommodate all offered features and when duplicate functionality technologies exist, this causes additional costs in the system.

When products are in later stages of development and deployment, information is typically shared through some of the same ways as discussed in the previous section, but the information shared is generally more rooted in data from real-world measurements of fuel efficiency improvements and other operating costs such as maintenance and infrastructure expenses, replacement costs, and resale value. From the responses from various stakeholders, it seems that there is diversity of opinion for the best ways to collect, share, and learn about real-world data and experiences with technologies. A number of interviewees shared that there are no easy tools available for sharing or learning about what is working and what is not. Smaller fleets and owner-operators provide insight into this credible information issue, which is evident "later" in a technology's adoption cycle. According to the survey results that are summarized in Figure 12, owner-operators highly value truck radio, trucking magazines, internet sites and truck shows and other fleets. It is important to note that the owner-operators' results are somewhat biased toward truck radio as that was the study team's method for contacting the large majority of this stakeholder population. The surveys also showed that owner-operators do not view the EPA's SmartWay Program or the fleets they are contracted to haul freight for as credible sources for information about new technologies as shown in Figure 12.

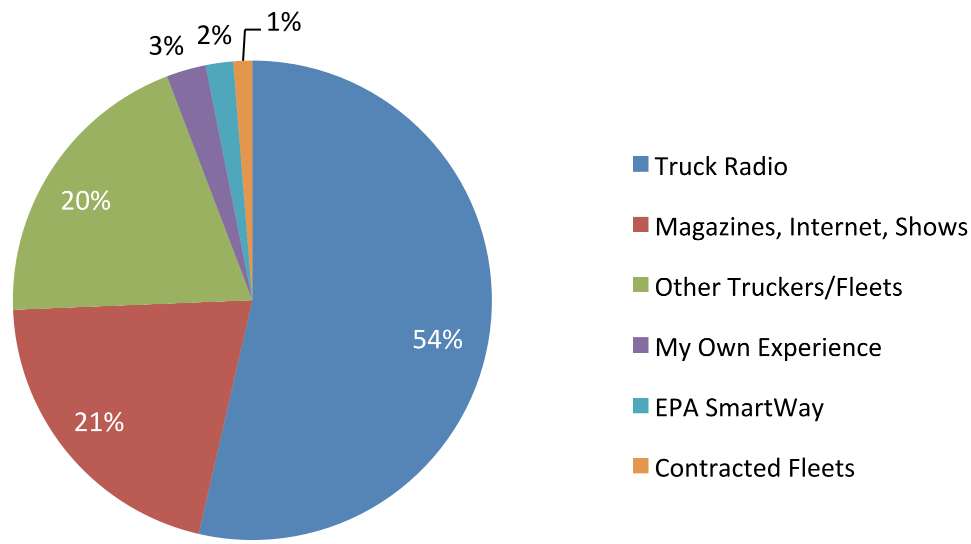

Figure 12. Owner-Operator Sources of Information

Figure 13 shows owner-operators' confidence in fuel-saving technologies and shows that 65% of respondents are either "Highly Confident" or "Confident" that there are technologies not currently being deployed on their tractors and/or trailers that can offer fuel efficiency improvement. From the online survey data and interviews with owner-operators at the Technology and Maintenance Council and the Mid American Truck Show, these results suggest that when they understand a technology, they quickly become confident in it. One owner-operator even stated, "That's the problem; there are no credible independent reviewing organizations, like a Consumer Reports."

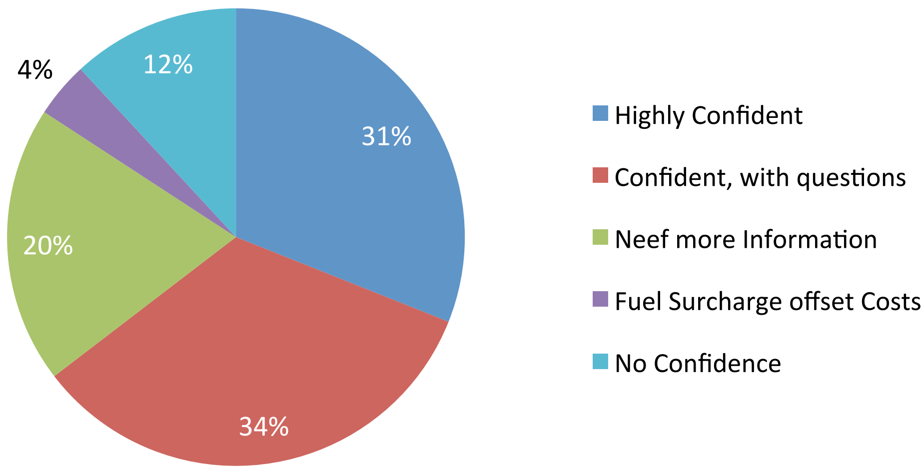

Figure 13. Owner-Operator Confidence in the Benefits of Fuel-Saving Technologies

Given that the targeted set of respondents for this data collection was "lead users" in both the fleet and supply chain interviews and the owner-operator surveys, this analysis is likely not fully representative of the fleets and owner-operators that own and operate the approximately 1.8 million freight trucks in the United States. To more fully understand this barrier, the study team reviewed the data and used the Mid America Truck Show to conduct various additional interviews with owner-operators, manufacturers and others, such as associations representing the industry. These discussions were valuable in understanding the issue of information sharing in the long-haul trucking sector.

Some quotes about information sharing practices are included here:

- "We are not big on hearsay, third-party operator experience like from one of our own owner-operators, or a small user that doesn't really do extended testing or data analysis. We'll consider testing [results] from a large valid carrier that we know and trust." - Vice President, large fleet
- "We'll seek information from other large fleets, my peers, first. Then test with a minimum of 30 units in our own fleet. Items need to be "driver proof" where it will work almost always regardless of driver engagement or not. Item must be robust and not break down, especially if it takes a unit out of service. - Vice President, large fleet
- "Most all the technology manufactures will run tests in our fleets at various locations, usually 6 months. New tractor, trailer dolly, trailer OEMs will also pilot the equipment in our fleet. Our team evaluates and recommends for capital purchase." - President and CEO of a large fleet

- The Director of Engineering at a private retail fleet said, "We gain awareness from other fleets, conferences, suppliers, etc., and if it makes sense then we'll put it into our 'engineering pipeline' where it will be studied, piloted, measured, evaluated, and then implemented if viable."
- "We'll consider outside data, but it's 'buyer beware'; source must have the technical knowledge and viable test data. Other fleets seem to have good data on maintenance costs of technologies, but the fuel efficiency data can be dubious…I do not have high confidence in their stated results. OEM data is ok as long as they're advertising it….truth in advertising." - Fleet Engineer at a private retail fleet
- "We look to partnerships with technology suppliers in adopting technology upgrades to our fleet. Testing is conducted and monitored by the supplier and decisions are made for utilization of the technology in the entire fleet." - Director of Transportation Operations and Logistics at a private retail fleet
- "A considerable amount of company time is spent with other fleets in the state trucking association and other groups where technologies are discussed and passed along." – Vice President of Operations, medium fleet
- The Director of ,On-Highway Vehicle Strategy for a truck OEM reported that all the information they tend to create and share on a give technology includes data from the "Lab, dyno, wind tunnel, [their] own test fleet, and key customers' test results."
- "Fleets often think the percentage efficiency improvement claimed by suppliers via their dyno tests and drive cycles are not realistic, and they are skeptical of the data. Worse case is fleet gets no advantage when implementing the technology but usual case is something like 'they promised 5% and I only got 2%,' so most fleets take the supplier stated results and cut them in half. Fleets put more credence in independent third-party testing (if available), what other similar fleets (like Customer Councils) are saying and best of all their own internal test results. Fleets look at big suppliers as pretty reputable and good 'advisors' to their business. They see these suppliers as partners in their drive for better freight efficiency…. Education is the key to running a fleet profitably. Some fleets will figure fuel efficiency on their own, the majority will use information and supplier data to help them, and some will not 'get it' via their poor fuel efficiency and will go broke." - Director, Vehicle Technologies at an established component supplier
- A Head Engineer for On-Highway Products at a truck OEM revealed, "We primarily focus on the big fleets that buy the most trucks but need to do a better job of reaching out the owner-operators and small fleets who make up the other 20% of the [sales] market."

As previously discussed, responses from all of the stakeholder groups evidence the strong desire of fleets to generate test results based on their own equipment, duty cycles, and business operations. A large fleet's Fleet Fuel Director stated, "We look at suppliers test results, but will 100% test ourselves on any new technology prior to implementation." As the team analyzed the interview data, it became clear that technology testing and validation is performed many times by multiple entities, often without much collaboration, as both suppliers and end users generally value self-generated data other any other external source. The General Manager of a truck OEM said, "Fleets know the 'real world' of freight movement, suppliers rely mostly on in-house controlled testing, and the OEMs are in the middle trying to make it all come together. There has to be an easier way." The Director of On-Highway Vehicle Strategy at another truck OEM commented on their responsibility to ensure appropriate application of technologies by stating that, "the commercial truck industry needs time to evaluate, test, design, produce, train and launch these technologies."

In summary, data and anecdotal evidence from trusted sources is the primary way that the late majority and laggard fleets gain confidence that fuel-saving technologies will work well in their operations. By their conversation nature, these organizations are avoiding the change to new technologies, and information must be presented to them via different means than innovator and early adopter fleets, which are more apt to proactively seek out information and test technologies for themselves. As technologies mature and reach higher levels of penetration, information from component manufacturers, truck and trailer OEMs, industry associations, and various media outlets (radio, internet) seem to have a larger influence on purchase decisions than when the technology is at early stages of development and deployment.

Inconsistent Reliability

The reliability of new technologies is often inconsistent, and that inconsistency is further exacerbated by suppliers and tractor and trailer OEMs not sufficiently testing before launch.

> "Will fuel economy features be as unreliable as emission ones (EGR components, diesel particulate filters, etc.)?" – from the focus group with truck dealers

Reliability of new trucks and trailers is paramount to fleets. Consumer expectations and the overall freight distribution system in North America depend on highly reliable equipment. Equipment must be available to perform every day and with little-to-no downtime. Given the slim margins of the trucking sector, any new technology has little room for error with respect to uptime of the vehicle. Multiple respondents stated this expectation that new technology should not impact reliability. As shown in Figure 7, reliability is the number one influencer for new truck specifications. In fact, as the trucking industry has been improving the basic quality of the equipment for over 15 years, the fleets expect that any new truck must perform better than the one it is replacing in their fleet (NACFE 2013).

Each of the stakeholder groups mentioned reliability as a significant concern with emerging fuel-saving technologies.

- A Marketing Segment Manager at a truck OEM shared that "We do full truck durability tests, full truck shaker tests, cab shaker tests, reliability growth testing as well as component testing."
- A Senior Manager of Supply Management at a rental fleet stated that "We have extensive analytic capabilities with respect to the reliability of components on equipment from the tractor and trailer builders. They are trying to improve this capability with respect to fuel-efficient components. We recently updated the engine parameter configurations on our base spec to be more fuel-efficient.

'Why not?' These parameters do not affect reliability and cost the same. We have also recently begun offering a 'max fuel economy package' for customers asking for a more fuel-efficient configuration for their leased trucks."

- A Founder and CEO of a new technology supplier voiced their commitment to provide reliable products: "We use fleets and third-party organizations to do testing for durability and performance."
- Another Vice President of Purchasing at a large fleet stated, "We once looked at very long cab extenders but before we tested it was obvious the reliability would be low and maintenance too high. We also believe that 13 liter engines won't be as long term durable as 15 liter engines, so we are not interested in making this switch to what could be more fuel efficient engines."

The truck dealers shared that "Quality and reliability issues with 2002 EGR and 2007 diesel particulate filter trucks were some of the worst we have ever seen." The dealers also shared that "Rapid change is killing fleets and OEMs. They [the truck and trailer OEMs] are having difficulty keeping up. New emissions rules and associated equipment every three years has been very difficult for the OEMs to support." A private fleet's Director of Engineering said, "With respect to fuel efficiency, it is important, but basic engine reliability is much more crucial to us than improved fuel efficiency, as we demand uptime and low cost of operation."

Interviewees shared that there seems to be more issues with early generation product problems than in past years. The dealers stated that, "Many of the products released to early adopter fleets before they are validated are creating poor performance and a bad reputation for the new technology. Tractor and trailer OEMs should better help weed out the good from the bad products and suppliers." Most of the industry leaders interviewed discussed this challenge with the study team. Field demonstrations are critical to new product development and validation, but it seemed that over the past decade too many problems with first generation products are creating a significant lack of confidence in trucking innovations. Finally, dealers also stated that, "As there simply have been too many issues, dealers and fleets no longer want to be field test partners", slowing the data accumulation that is so important for spurring adoption.

In some cases, a large number of suppliers emerge to try to take advantage of the opportunity that the innovation offers. The dealers, a few fleets, an OEM, and even some suppliers noted that in these cases this caused additional issues for adoption. The President of a new technology supplier mentioned, "At one point, there were about 20 manufacturers of both diesel auxiliary power units (APUs) and trailer side skirts; now the industry is coalescing around three and five." A large of amount of suppliers that are all trying to promote similar technologies can sometimes cause confusion with fleets. That same technology supplier shared that there seems to be an "industry-wide issue of first-to-market technology provider's products not delivering results as expected, and problems like this make users skeptical of that particular type of features and of new products in general." The industry is already risk averse, and prolonged adoption cycles will continue if purchasers are given a reason to doubt a new technology.

In summary, high reliability is a crucial determining factor for an end user to purchase a technology. Early adopter fleets understand that they will be part of the final validation, but too many problems with recent *new product launches have introduced additional elements of concern and skepticism, likely delaying or eliminating demonstration projects and adoption decisions.*

Lack of Technology Availability

Responses from various stakeholders suggest that a technology's availability as an option or standard feature at multiple truck or trailers OEMs generally takes years and nearly a decade for full availability across all OEMs.

"To get the technology we had to buy from a different truck brand, which caused many other problems and costs, until it was available from our preferred OEM"
– A Senior Fleet Manager at a private retail fleet

During the course of this project, the study team identified a barrier that has not been discussed much in the previous research in this area. A truck OEM's Director of On-Highway Vehicle Strategy said, "The pace of technology change is much faster than the truck OEM's [our] ability to implement. It's still a low volume industry with high specialization and a slower development cycle." Also, from a truck OEM's General Manager, "There is an intense internal review process including our own return on investment calculations. In order for a technology to reach large-scale levels of adoption, it must become a feature that is offered by most, if not all of the tractor or trailer OEMs."

A trailer OEM's Vice President and General Sales Manager described the "life" of an emerging trailer technology by stating that, "Technologies are adopted in phases: retrofitted at the fleet, assembled by upfitters during pre-delivery inspection, added at the trailer manufacturer, first on a per order basis, and later as a regular production offering, and then ultimately as a standard feature." He shared a real world example of tire pressure inflation systems for trailers. Currently, at this manufacturer, the axles are prepped for the trailer manufacturers with holes "drilled and tapped" for easier assembly. All axles meant for refrigerated trailers are "tire inflation prepped."

The study team created Figure 14 below, derived from information provided by various stakeholders during the interviews. It shows the various stages that a typical technology may move through as it becomes more widely used. Some technologies, such as trailer aerodynamic additions will begin life as retrofits at a fleet, and if successful the fleet will work with an OEM to get the device installed on their new equipment orders. Fleets stated that many times they will add the devices on new equipment before they put it into service and then OEMs might have their dealers or other "upfitters" install them after they manufacture the equipment and before it is delivered to the customer. Depending on the complexity of the technology, the first step in availability may be when the first OEM offers it as a customer specific per-order item. There is a standard practice within the tractor and trailer OEMs to engineer a particular feature solely for one customer, sometimes called order or special engineering. The feature is designed and integrated by the company only for that particular customer's needs and not for their entire product line specifications until such time the

OEM believes there will be high enough demand to justify the engineering. If a technology is gaining adoption and interest, more suppliers emerge and begin developing and supplying the same or alternative products to meet the functionality of the feature. As the technology is offered by more OEMs, later adopting fleets of all sizes and OEM-allegiances can decide to purchase the technologies. With the release of these new products by the OEMs, their dealers are trained and begin to promote the features to the larger industry, driving scale and lowering costs. Eventually, most if not all of the OEMs offer the device as standard in their product configurations and the laggards and non-adopters become users by default when they purchase new equipment.

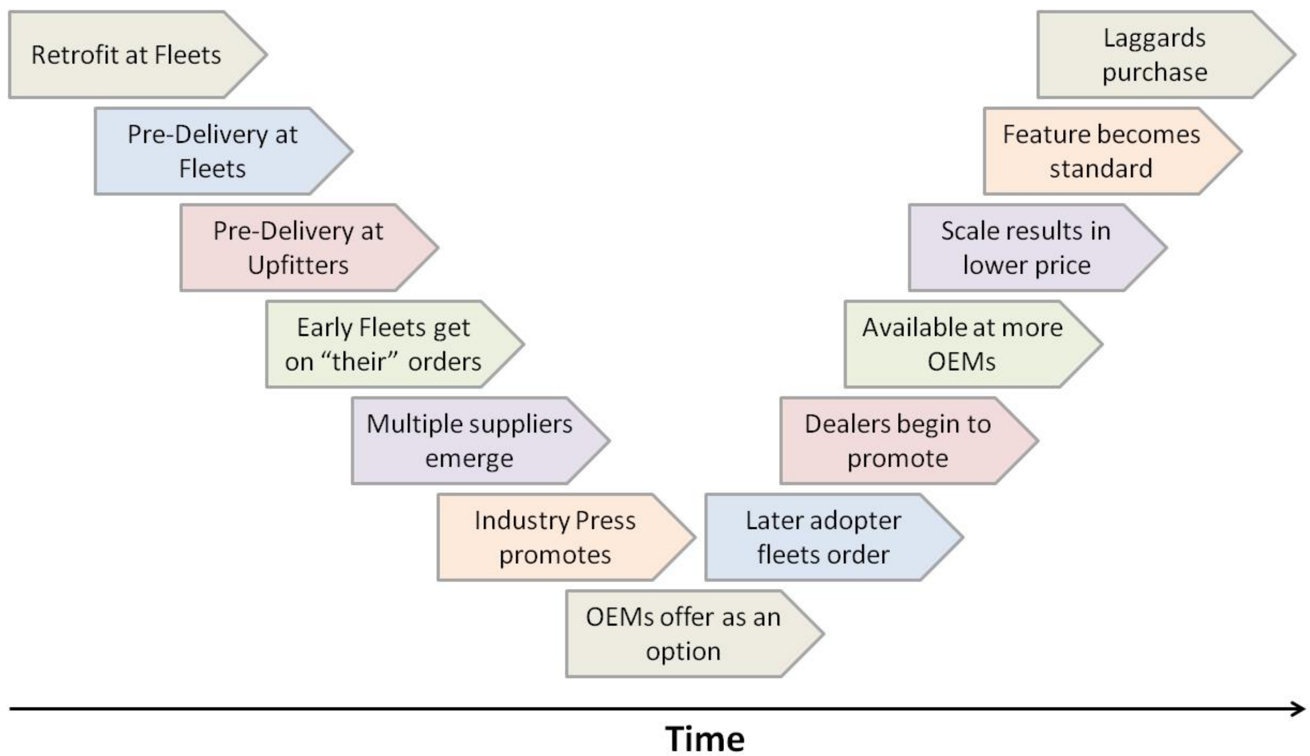

Figure 14. Example Life of a Technology over an Adoption Cycle

As the private fleet shared above, they believe that they made a mistake when they decided to purchase their trucks from a different OEM to get a particular new technology they highly valued. Availability of their desired features was not accessible from their preferred supplier. Many fleets and OEMs stated that their strategy around these technologies is to be "fast followers", meaning that as others take the lead in integrating the features into their products, they will follow quickly.

In analyzing the interview data and survey responses, a few other issues emerged regarding OEM's decision-making process on product offerings:

- Improvements to second and third generation products are not developed fast enough to correct the issues with the first generation. A few suppliers mentioned that the industry did not seem to support their product improvement efforts because the first products did not perform well enough.
- Some interviewees mentioned a "not invented here" issue within the industry. New technology companies or startups and their products are often not taken seriously.
- OEMs and manufacturers want assurances of future sales before integrating technologies into their product plans; however, these companies recognize that sales estimates for new products are very difficult if not impossible to accurately predict.

The truck OEMs had some high level views to share about early adoption and maturing technologies.

- "Early adopters expect issues with dealers as they know that they are ahead of the curve. But as the technology matures and scale is achieved, [a dealer's knowledge of technologies] becomes more important and later on with the laggards, a must." - General Manager
- A Product Manager of a truck OEM shared, "Most new technologies are pulled through by innovative fleets. They know their business well and try to be innovative. That is, customers ask us for it. Occasionally we push new technologies and groupings. One model [year] was a push – drive train, engine programming, and a feature grouping such as automated manual, etc. But generally customers ask for it in a 'Customer Adaptation' by submitting a feature request. We receive it and approve for their particular order. We then monitor requests and issue a 'Product Modification Request' or include the more popular features into major programs."

In summary, there are multiple redundancies in design, development, demonstration, validation, field testing, etc. with lack of good information sharing contributing to a very long availability timetable.

Additional Findings

In addition to the five barriers discussed above, the study team derived some additional findings that are addressed in the following section. These include specific technologies, driver retention, perspectives on regulations, the rebound effect and owner-operators' data.

Specific Technologies

As stated earlier, this study focused on the barriers to technology adoption rather than any significant work concerning the specific technologies themselves. The team did however ask the stakeholder groups and the owner-operators which technologies had the most short term potential for lowering the fleets' fuel expense with Figure 15 showing those results. The interviewers and the online survey asked the question, "Which technologies have the most potential in the short term?" Tractor aerodynamics, such as fuel tank skirts, cab extenders, aerodynamic mirrors and bumpers, scored the highest with respect to potential. Low rolling resistance tires and tires were valued next. Idle reduction is a broad category, which includes such technologies as auxiliary power units, idle shut down engine parameters, and truck stop electrification. Automated manual transmissions, 6x2 axles, and direct drive transmissions all show reasonable promise as identified by these stakeholders. The technology area in which the surveyed participants had the least amount of confidence was trailer aerodynamics, which includes such features as side skirts, boat tails and under trays.

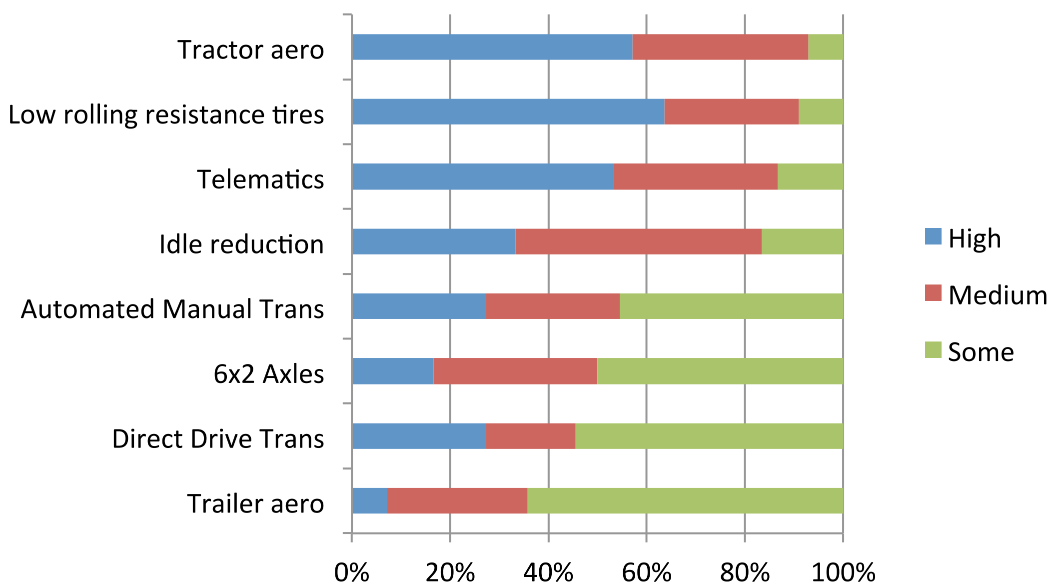

Figure 15. Technologies with Short Term Potential

Driver Retention

There is much discussion concerning driver attraction and retention in the trucking press and at industry conferences with respect to driver shortages and the challenge of high turnover at fleets. Figures 16 and 17 show driver retention data for for-hire and private trucking fleets (ACT Research 2013). In the figures data for 2005 to 2012 from the American Trucking Association (ATA) and the National Private Truck Council (NPTC) for the turnover of drivers in for-hire and private carriers, respectively, which are plotted using an identical scale for annual driver turnover on the y-axis. The stark contrast demonstrates the vast differences between driver retention in these two fleet types. Private fleet drivers are company employees of firms such as PepsiCo, UPS and Wal-Mart. In their annual fleet benchmarking work, the NPTC states that private fleet drivers are paid substantially better and receive superior training and benefits packages to their for-hire counterparts and that private fleets tend to hire drivers after they have been trained by and driven for the for-hire firms for about five years (NPTC 2011).

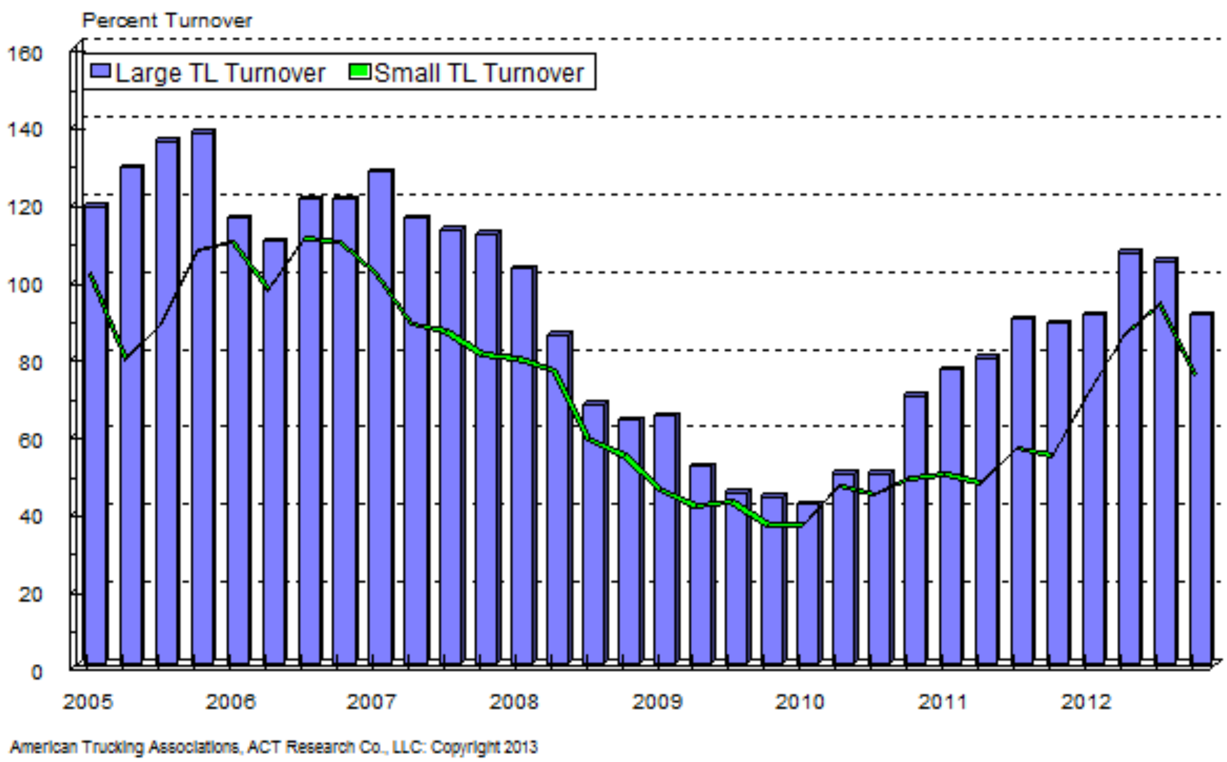

Figure 16. ATA: For-hire Truckload Carrier Driver Turnover

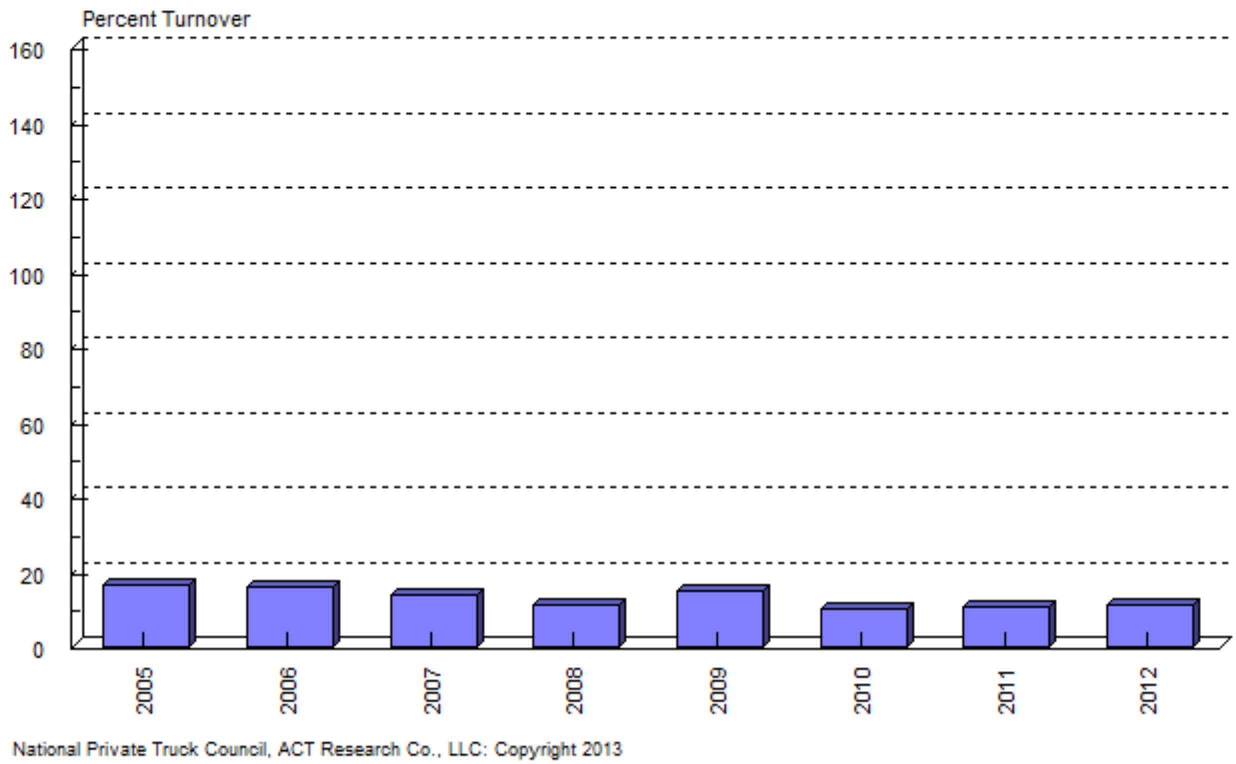

Figure 17. NPTC Benchmark Survey: Private Fleet Driver Turnover

With respect to barriers to increased adoption of fuel efficiency technologies, the interviewees indicated that driver retention impacts the choices fleets make concerning which features to pursue. For-hire fleets tend to favor technologies that require little to no driver intervention, while private fleets likely more often engage the driver in the technology choices. For example, a Vice President of one large for-hire fleet shared that they are retrofitting most of their trailers with automatic tire inflation systems to ensure the proper tire pressure without relying on the drivers to manually check them and take action. For-hire fleets generally do not have the ability to manage their drivers as closely as private fleets. An additional major reason for-hire fleets are different than private fleets in the type of technologies they adopt and why for-hire fleets favor *passive* technologies is that they simply don't see their equipment as often for maintenance purposes at their own facilities as do private fleets. Another example was described earlier in the section on lack of access to capital as for-hire fleets are specifying driver amenities such as electric HVAC, larger sleeper cabs and better riding cabs and seats in order to reduce driver turnover. The cost of purchasing of these devices can compete with the available capital for buying fuel-saving technology options.

According to many of the fleet interviews, there is a drastic lifestyle difference between for-hire and private fleet drivers. A private fleet driver typically has a regular schedule and can be home every night, while for-hire drivers often spend a large majority of working nights sleeping in the tractor. This is a significant factor in why driver turnover is so much lower for private fleets. For-hire companies are constantly competing for drivers and must purchase new equipment and driver amenity features on a regular basis or risk losing good drivers to other companies with newer equipment.

Split Incentive

In prior studies, the issue of a split incentive, also called a *principal-agent* problem, for fuel savings devices has been proposed. In one manifestation of the principal-agent problem in the trucking industry context, the entity buying the technology is not the same entity that must pay for the fuel, and therefore, the former will tend to avoid purchasing the fuel-saving technology due to the fact that they will bear the upfront cost, but not experience the associated savings. Vernon et al. (2012) studied this issue and suggested that the market structure of the trucking industry contributes to split incentives because entities responsible for investments in equipment do not always pay fuel costs, and drivers are not always rewarded for fuel-efficient operation. This study goes on to state that approximately 23% of trailers are subject to an “efficiency problem” when owners of rented trailers do not pay fuel costs. That study suggested that principle-agent problems have the potential to significantly discourage investments in fuel-saving technologies and can also result in insufficient maintenance and inefficient practices.

After analysis of the input from all end user stakeholders, the team found somewhat conflicting perspectives with regard to split incentives. Two very similar large fleets who tend to have high trailer-to-tractor ratios actually shared opposing opinions on the topic with respect to investments in trailer fuel-saving technologies. A Fleet Fuel Director for one fleet shared specifically that, “We found a trailer aero device to save 3%, but decided not to pursue it, as we have a high amount of independent contractors, who buy their own fuel, pull our trailers and we will not see the savings.” But another fleet executive, a Vice President, overseeing a fleet with basically an identical business model and truck duty cycle shared that, “we no longer take that into consideration. Most of our independent contractors buy fuel off our national contract and if they are healthier, in terms of profitability in their business, we will be as well.”

Another split incentive phenomenon is that of fuel surcharges, increases in the rates shippers pay carriers when fuel costs are higher than a set amount, was investigated. Again, fleets shared differing, if not opposite views. A President and CEO of a large fleet stated that, "We charge a fuel surcharge of 28.5% on almost all on-highway deliveries. This is a strong barrier to adopting an influence on corporate initiatives towards fuel-saving technologies." However, the Vice President of Operation of a medium-sized said, "We pay the contractors fuel use tax along with our fleet, and it is based on MPG usage of fuel, so it benefits us to have the owner-operator meet the best fuel efficiency.”

Perspectives on Regulations

As mentioned earlier, the study was focused on identifying the barriers to technology adoption, and during the course of the interviews with stakeholders, the topic of government regulations of pollutant emissions and fuel efficiency and GHGs emerged. Many end users and some of the supply chain companies discussed existing regulations and regulations in development and how these policy measures are affecting technology adoption. They referenced the EPA's engine emission standards, the California Air Resources Board's Tractor-Trailer GHG Rule and the EPA and NHTSA's fuel efficiency and GHG regulation. It is difficult to summarize the high diversity of comments, but the respondents shared that regulation can help accelerate the adoption of technologies, but it is very challenging to put in place rules that truly deliver the reduction of emissions and fuel use with an acceptable economic equation and to avoid unintended consequences in particular vocations. Also, many of the respondents were aware of, but not experts on these regulations.

Specific comments shared with the study team follow.

- The President and CEO at a Large Fleet said "All of our new equipment is specified with compliant technologies for the CARB rules in California. The new trucks operate there and we move older equipment to other states."
- "Weight, particularly driven by the addition of emissions equipment coming with the EPA compliance is becoming an issue. This can be 1,200 pounds and another 1,000 with a diesel auxiliary power unit. This can mean less payload and more trucks." – Vice President of Purchasing, a large fleet
- The President and CEO of a Used Truck Fleet stated, "The hours of service rules and emission regulations is a stopper to adopting technologies to save fuel."
- The Director of Operations and Maintenance of a used truck fleet shared that they may no longer be able to operate their older equipment. "We like to run these trucks up to 14 years old, but today CARB compliance is a major criteria for usefulness of equipment."
- "We had to reduce the cycle life of the power equipment [i.e. tractor trucks] in order to comply with CARB on-highway rules. The older equipment is moved to other states." - Director of Transportation Operations at a private retail fleet
- The Director of On-Highway Vehicle Strategy at a truck OEM shared a conundrum with respect to keeping older trucks longer: "Longer trade cycles are now required to amortize the more expensive EPA mandates." He went on to state that, "There is much focus on GHG requirements and fleets are concerned that they will be priced out of the market and unable to maintain any profit margins."
- The Manager of Advanced Engineering at another truck OEM echoed this sentiment: "Government regulations are accelerating quicker than the industry [we] can absorb."
- "It depends…Regulations could be a threat or an opportunity depending on how it is constructed." - Market Segment Manager of a truck OEM
- A Product Manager of a truck OEM stated, "[GHG regulations] won't change [the fact] that the fleet needs to understand his operation, and suppliers must help him get the right technologies for his specific needs."

- "CARB regulations have driven a significant adoption in wings [aero devices]" – Vice President of Engineering at a trailer OEM
- The President of a new technology supplier stated, "Regulations might be the only path to real adoption – a 'Paradigm Breaker'."
- "Many [end users and OEMs] are vested in the old school and if they have to do it, they will do the least necessary." - Founder and CEO of a new technology supplier

Rebound Effect

As part of the interviews, the end user fleets and the supply chain were asked about the phenomenon referred to as the rebound effect. In a whitepaper completed by the American Council for an Energy-Efficient Economy in August 2012, titled *The Rebound Effect: Large or Small? By Steven Nadel*, the rebound effect is described as "a postulate that people increase their use of products and facilities as a result of this reduction in operating costs, thereby reducing the energy savings achieved." Specific to passenger vehicles, they stated that, "More efficient vehicles cost less per mile for fuel, which can spur some car owners to drive longer distances or buy a larger or second car."

In a paper by Winebrake et al. (2012) "Estimating the direct rebound effect for on-road freight transportation", the authors reported a likely rebound effect of 4 – 24%, which is a large range based on the analytical timeframe and economic factors. They studied such factors as energy prices, energy efficiency data, demand for trucking, and demand for energy. Here they find that the LDV literature usually identifies a rebound effect of 5-20% in the short run and 10-30% in the long run, translating to a .05 to .3% increase in vehicle travel for every 1% increase in fuel efficiency. This article recommends measuring the relationship between trucking services demanded and the energy price of trucking.

If this is true, one would expect that as fuel efficiency increases dramatically for the overall trucking fleet, the demand for trucking services will increase as well. To try to investigate whether this phenomenon is present at the individual fleet level, the team asked the fleets about the potential and size of the rebound effect in their own trucking operations. Trucks are used as tools in business for transporting goods, and the cost of goods movement is a direct cost that is passed on to consumers. The movement of goods is highly scrutinized for cost, and the study team recognized the high attention to cost when developing a question to better understand the potential of a rebound effect. The hypothesis for a rebound effect was that trucking fleets would be less demanding concerning operational factors such as out-of-route miles, speed limiting, less focus on back hauls, etc. if the efficiency of their vehicles were drastically improved.

The question was framed in the following way: "If your fleet were to achieve a significant fuel savings, say 1.0 MPG or about a 15% improvement, what would you do differently in your operations?" Nearly all of the interviewees struggled to answer this question. A few of the most compelling responses are listed below.

- "We could eventually lower freight pricing due to lower fuel costs."

- "[We would] Quickly adopt the practices to our other applications and divisions."
- "We did it, now keep being aggressive with all opportunities, even with CNG tractors."
- "Become more aggressive in technologies outside of mandated ones."
- "Lower our trade cycle, since we know our future trucks will have better MPG."

In some cases, the interviewer asked if better MPG might encourage more miles being driven by trucks and universally the response was "absolutely not." Given the industry history of attention to these metrics, tools emerging that assist this management such as GPS and routing, the study team believes there is little to no rebound effect in the on-road freight sector.

Owner-Operator Data

This study is unique due to the high number of owner-operator participants (1,892) that were reached through the use of online surveys. As mentioned before, the survey was sent to two owner-operator stakeholder groups: Cascade Sierra Solutions owner-operator contacts and Kevin Rutherford's *Lets Truck* Sirius XM stakeholder group. The perspectives of this group of owner-operators and small companies are interspersed throughout the report, where appropriate. Listed below are additional data summaries from the survey results.

- 95% have five or fewer trucks in their fleet
- 49% own their own trailers
- 75% consider themselves to be long-haul
- 122,099 average miles driven per truck in 2012 with the responses ranging from about 50,000 to 200,000
- 6.6 average miles per gallon reported
- 59% lease their trucks to a fleet
- 74% would retrofit their existing tractor rather than wait until they bought another to employ fuel-saving technologies
- 77% would replace their existing tractor with a more efficient used tractor rather than buy a new tractor
- Purchasing decisions are most influenced by fuel efficiency and reliability

IV. Conclusions and Recommendations

Fuel costs for on-road truck owners and fleets are on average 35% of their total operating expense. With the cost of fuel steadily increasing, conventional wisdom would dictate that available technologies to improve fuel economy efficiency would be widely adopted by the trucking sector. However, in reality, this is not the case as there are a number of available technologies shown to improve fuel economy that have had limited adoption to date. This report sought to investigate the prevailing barriers that stand in the way of the greater adoption of fuel-saving technologies for tractor-trailers in N. America. The study included a unique survey approach that amassed the perspectives of a number of critical decision makers throughout the long-haul industry sector: from fleets, to manufacturers, to integrators and builders, to dealers, to equipment leasers, to shippers, and owner-operators to better assess the complex set of issues that govern decisions about technology development and investment. By design, the study participants are probably more likely to be more technology progressive than the industry as a whole. Consequently, the barriers identified in this study are likely even more pronounced for the industry as a whole. The study identifies barriers in many areas and at key decision-making junctures that limit the large-scale deployment of available efficiency technologies for tractor-trailers. The five primary barriers that have been discussed in this report as well as additional relevant findings about split incentives and the rebound effect are summarized below.

Uncertainty about Payback – Universally, fleets make decisions to buy new technologies using a payback calculation, and manufacturers and technology suppliers utilize similar payback calculations in determining what technologies or technology packages to bring to market. Two distinct themes emerge: (1) short paybacks (i.e. 2-3 years or less) are expected by the industry, and (2) payback calculations are not very well defined or consistent across the industry, partly due to the high degree of heterogeneity in the trucking business. As supported by the interview responses, a general rule-of-thumb is that new technologies must meet a payback requirement on the order of 18 months for for-hire fleets, which tended to have the shortest ownership cycles and expected payback times out of all of the end user groups. In fact, it seems that product development for the entire industry seems to be driven by what is required for for-hire fleets. In addition, payback calculation methodologies vary widely across the industry in terms of comprehensiveness and consistency. However, a common theme across all of the end users groups was a strong tendency towards risk aversion, which is certainly reflected in their assumptions for the fuel consumption reduction potential of technologies

Lack of Capital – Often, there is a lack of capital for acquiring new technologies. It was found that in some cases, even after the fleet has confidence that a technology would deliver a payback for their operations, lack of access to capital for purchasing technologies is an issue. Adjusting for inflation, new truck costs have increased by roughly 20 - 30% over the past 5-7 years, and the money a fleet can spend on fuel efficiency features may compete against other features such as cabin amenities to better attract and retain drivers as well as other new technologies for improved safety, communications, routing, etc.

Lack of Credible Information (verifying and sharing) – Credible information is an overarching barrier that can be broken down into two main issues: (1) verifying information early in the product cycle and (2) sharing information later in the product cycle. There is difficulty obtaining accurate data on new technologies to make adoption decisions early in a technology's life. Verifying technologies in the early stages of its life cycle is challenging, and redundant testing efforts are commonplace as fleets are hesitant to trust the claims made by technology suppliers and OEMs. End users struggle with the lack of confidence in outside information coupled with belief that they need to perform customized testing to determine the appropriateness of the technologies for their specific fleet. Self-generated reliable data comes at a high cost that many end users are unwilling or unable to pay.

As new technology is successfully adopted by the innovators and early adopters, the information is many times not consistently disseminated to the industry as a whole. More often than not this information is shared informally and inconsistently through anecdotal means. The sharing of data between credible, trusted sources is the primary tool for the later adopting fleets to accept the technologies in their operations. For most end users, this study suggests that second to self-generated data, fleets and owner-operators are most influenced by their peers, that is companies (or individuals) engaged in similar trucking operations. The lack of standardized information and/or platforms for information sharing creates less confidence for the early and late majority adopters to invest in technology and slows adoption cycles.

Insufficient Reliability – Not surprisingly, reliability tends to be inconsistent on new technologies and product lines. The on-road trucking sector is extremely adverse to any sort of reliability issues in their equipment. Downtime translates directly to profit losses, and therefore avoiding downtime is a constant battle most end users are tackling daily. Moreover, many early generation products develop initial reputations for being unreliable, and even when these issues are resolved in subsequent generations, the original stigma of unreliability is still attached to these technologies.

Lack of Availability – Due to the extended maturation and uptake cycles in the on-road truck market, many technologies take a significant length of time (many years) to become widely available across a number of different manufacturers. Lack of availability is a clear barrier to market penetration.

Aside from the five main barriers discussed above, there are additional interesting findings from this study. These are summarized below:

Split Incentives – The split incentive (i.e. the entity paying for the fuel is not the entity paying for the technology) has long been considered a key barrier to technology adoption. This study found that the split incentive is not as critical as once was perceived, mainly due to the fact there are less and less cases where the technology buyer will see zero benefit (direct or indirect) from improved fuel economy. Although the split incentive was not found to be universal enough to be included in the top list of barriers, there are still situations where it is very important. The most obvious of these is in the area of trailer technologies. There are many available cost-effective trailer technologies that can improve fuel efficiency (NACFE 2013), yet there is still a barrier to adoption due to ownership dynamics. A significant amount of tractor owners do not pull their own trailer and therefore trailer owners would see no direct benefit from upgrading their trailer. This split incentive for trailers is most prevalent in the for-hire fleets and less so for retail/private fleets and owner-operators, where many trailers are pulled by their owners.

Rebound Effect – Overall, this study found that rebound effects, defined as the extent to which benefits from efficiency improvements are counteracted by increased usage, are negligible. The literature suggests that the rebound effect can be difficult to measure (or even define). The results from this study are merely qualitative and should be taken as such. Overall, the fleets surveyed were adamant that no additional usage would occur if they were to realize a significant fuel economy improvement in their fleet. Instead, those savings would be invested or directed elsewhere into strategies that will help improve their market competitiveness, such as into new technologies or lower charges for goods movement.

Recommendations for Future Work

Based on the results of this study, we propose the following areas for future work. Further studies should be conducted to look at measures to address some of the barriers identified in this study. The most pervasive barrier, the lack of credible information, is the logical first one to focus on due to the fact that it impacts all of the remaining barriers to some extent or another. Future efforts should focus on practical and credible methods for validating technologies and disseminating the information in a reliable and consistent way. Policy measures should be pursued if they can effectively promote technologies that are delivering economic benefits and limit the adverse consequences on the industry as a whole.

References

Ansar, J. and Sparks, R. 2009. "The Experience Curve, Option Value, and the Energy Paradox." *Energy Policy* 37 (3): 1012-1020.

Carbon War Room. 2012. *Road Transport: Unlocking Fuel-Saving Technologies in Trucking and Fleets.* Available online at http://www.grahampeacedesignmail.com/cwr/cwr2012_trucking_finall_download_singles.pdf

CE Delft. 2012. *Market Barriers to Increased Efficiency in the European On-Road Freight Sector*. Available online at http://www.theicct.org/market-barriers-increased-efficiency-european-road-freight-sector

US Bureau of Labor Statistics.2013. Consumer Price Index (June 18, 2013). Available online at http://stats.bls.gov/cpi/#tables

US Department of Energy (DOE). 2009. Research and Development Opportunities for Heavy Trucks. Available online at http://www1.eere.energy.gov/vehiclesandfuels/pdfs/truck_efficiency_paper_v2.pdf

US Energy Information Administration (EIA). 2013. Gasoline and Diesel Fuel Update (June 24, 2013). Available online at http://www.eia.gov/petroleum/gasdiesel/

Ellram and Golicic. 2011. *Environmentally Sustainable Transport.* Executive summary available online at http://www.cascadesierrasolutions.org/libsmartway.aspx

Goodyear Dunlop Tires Europe. 2012. *Driving Fleet Fuel Efficiency: The Road to 2020.* Available online at http://www.cadenadesuministro.es/wp-content/uploads/2012/01/Driving-fleet-fuel-efficiency-The-Road-to-2020-informe-Goodyear-Dunlop.pdf

International Energy Agency (IEA). 2009. *Transport, Energy and CO_2: Moving Toward Sustainability*. Available online at http://www.iea.org/publications/freepublications/publication/transport2009.pdf

Jaffe, A. and Stavins, R. 1994. "The Energy Paradox and the Diffusion of Conservation Technology." *Resource and Energy Economics* 16 (2): 91-112.

Liimatainen. H. et al. 2012. "Energy Efficiency Practices Among Road Freight Haulers." *Energy Policy* 50: 833-842.

North American Council for Freight Efficiency (NACFE). 2013. *Fleet Fuel Study, March 2013*. Available online at http://nacfe.org/wp-content/uploads/2013/03/2013-NACFE-Study-Major-Findings-030713.pdf

Nadel. 2012. The Rebound Effect: Large or Small? An ACEE White Paper, available online at http://aceee.org/files/pdf/white-paper/rebound-large-and-small.pdf

National Academy of Sciences (NAS). 2010. *Technologies & Approaches to Reducing the Fuel Consumption of Medium and Heavy-Duty Vehicle.* Available online at http://www.nap.edu/catalog.php?record_id=12845

Northeast States for Coordinated Air Use Management (NESCAUM). 2009. *Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions.* Available online at http://www.nescaum.org/documents/heavy-duty-truck-ghg_report_final-200910.pdf

National Private Truck Council (NPTC). 2011. *Benchmarking Survey 2011*. Available online at http://go.postbidship.com/rs/postbidship/images/2011-NPTC-Benchmarking-Survey-Results.pdf

National Renewable Energy Laboratory (NREL).2013.http://www.nrel.gov/news/press/2013/2138.html *Transportation Energy Futures - March 2013, Project Overview and Findings* – Ref: NREL/PR-6A20-56270.

Price Digest. 2013. The Truck Blue Book. Available online at http://www.truckbluebook.com

Rogers, Everett M, 1962. *Diffusion of Innovations.* Glencoe: Free Press. ISBN 0-612-62843-4. 150

Shama, A. 1983. "Energy Conservation in US buildings: Solving the Potential/Low Adoption Paradox from a Behavioural Perspective." *Energy Policy* 11 (2): 148-167.

TIAX. 2009. Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles. Contract Number: DEPS-P290355. 3-11 – 3-16

Vernon, D. and Meier, A. 2012. "Identification and Quantification of Principal-Agent Problem Affect Energy Efficiency Investments and Use Decisions in the Trucking Industry." *Energy Policy.* 49: 266-273

Von Hippel. 2005. *Democratizing Innovation*. The MIT Press. Cambridge, Massachusetts.

Appendix A: List of Exhibits

Appendix B: Example of an interview template (used for large and medium sized fleets)

ICCT 'Barriers to Technology' Fleet Carriers Questionnaire

The International Council on Clean Transportation (ICCT) has undertaken a study of the market characteristics in the goods transportation by class 7 & 8 tractors to identify the 'barriers to technology' adoption that currently exist in the U.S. on-road freight sector. The results of this study will help our trucking industry to identify the initiatives and measures that can be most effective in combating those barriers.

It is important to understand the process that fleet owners use to arrive at decisions for capital purchase in acquiring new vehicles, technologies, along with establishing standards of 'best practices' to achieve greater fuel efficiency. The cost of fuel impacts trucking fleets of all sizes, and technologies with relatively short payback times can see limited adoption due to prohibitive up-front costs, risk aversion to new technology, or a disincentive to invest in more fuel-efficient equipment. This study will collect and present the barriers in a final report and presentation to ICCT.

Interview Date:	
Interview Conducted By:	**In Person** ________ **Conference Call** ________
Interviewer Conducting Interview:	

1. **Company Information**

Name of Company		
Contact Person Contact Details		
Fleet Vehicle Information	Number of Power Vehicles _________ Number of Operation Centers _________ Number of Maintenance Facilities ______	Class 8 Vehicles _______ Class 7 _______ Number of Trailers__________ Number of Drivers __________
Fleet Market Application	Over-the-Road Long Haul ________ Truck Load (TL) ________ Less Truck Load (LTL)_______ Bulk _______ Van ________ Size of Van Trailer ______	Pickup & Delivery ________ Intermodal ________ Container _______ Contract Carrier _______ Refrigerated ________ Flatbed ________
Company Ownership	Self ________ Family ________ Stockholder Group ________ 3PL __________ Other Company ________ Name of Other Company ____________________________	
Fleet Market Area	48 States + Canada _______ Regional _________ (Regions Coverage) _____________ City / Urban / Rural ___________ Name of City _______________________________	

Notes:

*Note** All company information will not be shared or distributed beyond the survey interview protocols of data collection without express permission of the company.*

(Surveyors' initials)________________________

General Barriers to the Implementation of Energy Efficient Technology Measures

The American Transportation Research Institute (ATRI) September 2012 analysis "Operational Costs of Trucking" outlined that fuel costs have risen nearly 10 percent in the first eight months of 2012. Fuel efficient technologies for power equipment and trailers have had a major influence on the decisions by fleets to control the cost of fuel. The following questions will focus on the process of evaluating to adopt fuel saving technologies.

1. What is your process to determine if a technology is a good investment for your fleet?

   ____

   ____

2. Ask the 7 common questions.
   a. Rate the importance of the following factors when putting together specifications for new equipment.
   b. What is the necessary payback?
   c. Which factors influenced your decision not to install a technology and rate its importance?
   d. How do you evaluate new technologies for adoption?
   e. When researching a technology, how do you value the information from these various sources?
   f. Which technologies do you see having the most short-term potential?
   g. If your fleet has adopted technologies that deliver a 1 mpg, 5% improvement, what effect would this have on your operation?

3. How do you calculate ROI? (Please indicate the following that apply to your calculation)

   Total cost of ownership (TCO) _____ Incremental cost of technology _____ Maintenance _____

   Durability cycle _____ Residual value _____

4. When considering technologies for adoption into your fleet, how do you determine whether to buy it only on new equipment, retrofit only on old equipment or both?

5. A number of the 'alternative' fuel options currently provide a considerable reduction in the price of fuel compared to diesel. Please indicate your position on the 'alternative' fuel option for your fleet:

_____ Currently considering 'alternative' fuel technology – LNG _____ CNG _____ Bio-fuels _____
_____ Wait for technology to mature in the industry – LNG _____ CNG _____ Bio-fuels _____
_____ Not considering the 'alternative' fuel technology

Notes and Comments: ____

6. Does your organization contract with Owner-operators and small independent fleets?

Yes _____ No _____

If 'Yes', does your contract require the Owner/Operator or small independent fleets to meet a technology threshold established for your fleet with the vehicle and/or trailer they have under the contract?

Yes _____ No _____

7. In evaluating the cost of complying with regulations for existing fleets, does this restrict the adoption of fuel efficiency technologies that have been determined to work for your fleet?
Yes _____ In some instances _____ No _____

2a. Please explain ____

____

8. Would you consider a fuel efficient technology for your fleet even though the technology does not assist your fleet in meeting emission regulation mandates?

Yes _____ No _____ Open to consideration _____

***Special Question**Your fleet has been selected to participate in this survey because of the value of your responses which will assist in discovering the barriers that exist to the adoption of fuel efficient technologies. Would you commit to become a stakeholder in a future effort to examine the solutions to these barriers which would include an internet based survey?*
Yes _____ No _____

Appendix C: Common questions template

All in-person and telephone interviews were asked a set of Common Questions with possible answers predetermined as drop down menus in the interviewer's template. The interviewer tried to ask all questions, but due to time constraints had to prioritize which ones to get answers. This data was used to compare responses amongst different stakeholder groups. Supply Chain interviewees were sometimes asked to answer the question as if they were a fleet, or how they believe the fleets would answer.

1. Rate the importance of the following factors when putting together specifications for new equipment.
    a. Fuel Economy
    b. OEM make/model
    c. Mandated regulations
    d. Application drive cycle
    e. Reliability
    f. Driver recruitment/retention
    g. Resale value
    h. Fleet image
    i. Durability/longevity
    j. Maintenance
2. What is your necessary payback?
    a. What is the needed payback to purchase a technology?
    b. Do grants influence your purchase?
    c. Given your trade cycle, what is the absolute maximum payback you would consider?
3. Which factors influenced your decision not to install a technology and rate it's importance.
    a. Research data suggested this technology was not appropriate for your fleet
    b. Available data was not relevant to your operations.
    c. Although available data suggested it would work, you were not convinced
    d. No outside validation of manufacturers claims
    e. The testing methods for the data did not meet your standards
    f. Gathering the data yourself was too expensive or time-consuming
    g. Product support/warranty was not adequate
    h. Additional maintenance and overall lifecycle cost were too high
    i. Weight of the new technology was too much
    j. The technology was not available from your preferred equipment dealer
    k. Concerned about disruptions/negative impacts on your operations
    l. Your drivers did not like the technology
    m. Buying and installing the technology was simply too expensive
4. How do you evaluate new technologies for adoption?
    a. Do you require suppliers to test product by a third-party?
    b. If so, what percentage of the cost do they pay?
    c. Do you require a trial run in your fleet?

   d. If yes, how many units would you test?
   e. How many months would you run the test?
5. When researching a technology, how do you value the information from these various sources?
   a. Technology manufacturer
   b. EPA SmartWay
   c. Third-party validation
   d. Other fleets at an event like TMC
   e. Other fleets experience
   f. Other testing reports
   g. OEM and dealers
   h. Your own research capabilities

   Looking at the source you scored highest, to what degree does it influence your decision?
6. Which technologies do you see having the most short term potential?
   a. Low rolling resistance tires
   b. Tire inflation / monitoring systems
   c. Idle reduction
   d. Trailer aerodynamics
   e. Tractor aerodynamics
   f. Automated manual transmissions
   g. 6x2 axle configurations
   h. Direct drive transmissions
   i. Telematics
7. If your fleet has adopted technologies that deliver big savings, 1 mpg or 15% improvement, what effect would this have on your operations?
   a. What might you do differently?
   b. Decisions / actions in your fleet?

Appendix D: Questions in the Owner-operator Survey

ICCT Technology Barriers Owner-Operators Survey

The International Council on Clean Transportation (ICCT) is studying owners of Class 7 and 8 tractors to identify the barriers preventing the adoption of fuel-efficient technologies in the U.S. on-road freight sector. The results of this study will help policy makers in the U.S. and other regions around the world assist in removing those barriers.

We're interested in knowing the factors that influence Owner/Operators in acquiring new vehicles, technologies, and practices to achieve greater fuel economy. Although the cost of fuel is a large consideration for fleets, many fuel-saving technologies are still experiencing limited adoption for other reasons. This study will collect and present the barriers in a final report and presentation to ICCT.

Please note that your survey responses are anonymous, and we will only share the data collected for the report with our stakeholders.

We'd like to know what criteria you use for evaluating whether to adopt new fuel saving tractor-trailer technologies for your equipment. Please answer the following questions.

What is your confidence level that fuel saving technologies would benefit your operation?

- Highly confident
- Confident, but with questions
- Need more information
- Fuel surcharge offsets fuel costs
- No confidence

What is the main credible source you depend on for gathering information on which fuel-saving technologies might work for your organization?

- EPA SmartWay
- Trucking trade magazines/Trade shows
- Contracted Fleets
- Other truckers or fleets
- Truck radio
- Other (please specify)

What is the current MPG on your vehicle today? If you have multiple vehicles, what is the average?

Current Miles Per Gallon (MPG) ______

What improvement in MPG (miles per gallon) is necessary for a technology to be considered for adoption on your equipment combination?

- 0.3 MPG or less
- 0.5 MPG
- 0.8 MPG
- 1.0 MPG or more

Do you own your trailer equipment?

- Yes
- No

How important are the following trailer fuel-saving technologies when determining how to configure your trailer? (Please click and drag items to arrange in order of highest importance)

- Low Rolling Resistance Tires
- Tire Air Pressure Inflation / Monitoring System
- Trailer Gap Reduction
- Trailer Skirts
- Trailer Boat Tail System
- UnderTray System

Do the trailers you haul influence your decision to implement fuel-saving technologies on your tractor?

- Yes
- No

How important are the following trailer fuel-saving technologies when determining how to configure your tractor? (Please click and drag items to arrange in order of highest importance)

- Low Rolling Resistance Tires
- Tire Air Inflation / Monitoring System
- Trailer Gap Reduction
- Trailer Skirts
- Trailer Boat Tail System
- UnderTray System

The cost of the technologies and their installation can be a considerable investment. Would you be more inclined to wait to purchase a newer tractor with the technologies included, or would you choose to retrofit the technology on your existing tractor?

- Purchase or lease newer tractor
- Retrofit existing tractor

Please indicate what you would choose to retrofit to provide the best recovery of your investment.

- Low Rolling Resistance Tires
- Idle Reduction
- Aerodynamic Devices
- Other (please indicate)

When deciding to replace your existing tractor equipment will your first option be to trade for a

- Newer, more efficient USED tractor
- NEW, latest model year tractor

Please rank the following considerations in order of importance in making your purchasing decision (Click and drag each item below to re-order based on your preferred order of importance.)

- Fuel efficiency
- Price
- Mileage
- Make/Model
- Estimated useful life remaining
- Complies with regulations
- Reliability

What do you feel is a reasonable payback period for an investment in fuel efficient technologies on a USED tractor?

- Less than 12 months
- 12-24 months
- 24-36 months
- More than 36 months
- None of these

Please rank the following considerations in order of importance in making your purchasing decision (click and drag each item below to re-order based on your preferred order of importance.)

- Fuel efficiency
- Price
- Financing available
- Make/Model
- Engine/Transmission
- Ability to choose best specs for your vocation
- Warranty/Support

What do you feel is a reasonable payback period for an investment in fuel-efficient technologies on a NEW tractor?

- Less than 12 months
- 12-24 months
- 24-36 months
- More than 36 months
- None of these

Numerous options exist for upgrading a tractor for better fuel efficiency. If you were preparing to purchase a newer tractor, please let us know which options you'd consider installing, and your previous experience using them, in the following categories:

Tires

	Currently use and would use again	Would use depending on cost and financing	Never used but would consider in the future	Have used but would not use again	Never used and would not consider using	Not familiar with/Not applicable technology
Low rolling resistance tires	○	○	○	○	○	○
Single wide tires	○	○	○	○	○	○
Automatic tire monitoring/inflation	○	○	○	○	○	○

Idle Reduction

	Currently use and would use again	Would use depending on cost and financing	Never used but would consider in the future	Have used but would not use again	Never used and would not consider using	Not familiar with/Not applicable technology
Diesel auxiliary power units (APUs)	○	○	○	○	○	○
Battery-operated auxiliary power units (APUs)	○	○	○	○	○	○
Electric shore power connection	○	○	○	○	○	○

Aerodynamics

	Currently use and would use again	Would use depending on cost and financing	Never used but would consider in the future	Have used but would not use again	Never used and would not consider using	Not familiar with/Not applicable technology
Integrated roof fairings	○	○	○	○	○	○
Cab side extenders	○	○	○	○	○	○
Aerodynamic mirrors/bumper	○	○	○	○	○	○
Fuel tank side fairings	○	○	○	○	○	○

Powertrain

	Currently use and would use again	Would use depending on cost and financing	Never used but would consider in the future	Have used but would not use again	Never used and would not consider using	Not familiar with/Not applicable technology
Dead 6 x 2 axle	○	○	○	○	○	○
Automated manual transmission	○	○	○	○	○	○
Direct drive transmission	○	○	○	○	○	○

1. **Have you ever considered installing a particular fuel saving technology on your truck/s, but chose not to?**

○ Yes
○ No

Please indicate the degree to which the factors below influenced your decision not to install the technology?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
Research data suggested this technology was not appropriate for your truck or fleet	○	○	○	○	○
Available data was not relevant to your operation (either vehicle make or duty	○	○	○	○	○

cycle).					
Although available data suggested the technology would work, you weren't convinced it would. Why not?	○	○	○	○	○
No outside validation for manufacturer's claims.	○	○	○	○	○
The testing methods for the data did not meet your standards.	○	○	○	○	○
Gathering the data yourself was too expensive or time-consuming.	○	○	○	○	○
Product support/warranty was not adequate.	○	○	○	○	○
Additional maintenance and overall life-cycle costs were too high.	○	○	○	○	○
Weight of the new technology was too much.	○	○	○	○	○
The technology was not available through your preferred equipment dealer.	○	○	○	○	○
Concerned about disruptions/negative impacts on your operation from the technology.	○	○	○	○	○
You/your drivers did not like the technology.	○	○	○	○	○
Installing the technology was too expensive	○	○	○	○	○

Did you seek outside funding for the installation?

- ○ Yes
- ○ No

If yes, were you able to find it?

- ○ Yes
- ○ No

Emission Regulations/Compliance and Maintenance Issues

In your experience, how much of a factor are engine problems/downtime in considering an investment in more fuel-efficient tractors for your fleet?

- Not a consideration
- One of several considerations
- Primary consideration

Emissions-reduction technologies are required to comply with air-quality regulations in some areas. Does the cost of these mandates restrict your ability to invest in other fuel-efficient technologies?

- Yes
- In some instances
- No

How many trucks do you have in your fleet?

- Five or fewer
- More than five

What is the average annual mileage for a truck in your fleet?

Annual Miles

Do you lease your truck/trucks to a fleet?

- Yes
- Yes, contracted to dedicated customers
- No, have my own authority

Vocation