NCEE
NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS

Heavy-Duty Trucking and the Energy Efficiency Paradox

**Heather Klemick, Elizabeth Kopits,
Keith Sargent, and Ann Wolverton**

Working Paper Series

Working Paper # 14-02
January, 2014

U.S. Environmental Protection Agency
National Center for Environmental Economics
1200 Pennsylvania Avenue, NW (MC 1809)
Washington, DC 20460
http://www.epa.gov/economics

Heavy-Duty Trucking and the Energy Efficiency Paradox

Heather Klemick, Elizabeth Kopits,
Keith Sargent, and Ann Wolverton

NCEE Working Paper Series
Working Paper # 14-02
January, 2014

Heavy-Duty Trucking and the Energy Efficiency Paradox

Heather Klemick, Elizabeth Kopits, Keith Sargent, and Ann Wolverton[1] [2]

Abstract: Economic theory suggests that profit maximizing firms should have an incentive to incorporate technologies into their products that are cost-effective, absent consideration of externalities. Even in the presence of uncertainty and imperfect information – conditions that hold to some degree in every market – firms are expected to make decisions that are in the best interest of the company owners and/or shareholders. However, simple net present value calculations comparing upfront costs of fuel-saving technologies to future savings suggest this is not always the case. This puzzle has been observed in a variety of contexts and is commonly referred to as the "energy efficiency paradox." A growing number of empirical studies in the peer-reviewed literature examine why households may under-invest in energy efficiency. To our knowledge, far fewer studies examine whether similar undervaluation occurs on the part of businesses. While a variety of hypotheses could explain this behavior, lack of empirical evidence on why businesses do not always invest in seemingly cost-effective energy saving technologies limits our ability to judge whether and when a given hypothesis is likely to be valid. In this paper, we explore capital investment decisions within the heavy duty trucking sector for fuel-saving technologies. Given the lack of readily available data sources to study this industry, we collect information via a combination of focus groups and interviews. While the sample is not representative, we gain insight into what factors might explain apparent underinvestment in emission reducing technologies absent government regulation.

Key words: energy efficiency paradox; technology investment decisions; heavy duty trucking

JEL codes: Q52; Q48; Q58

[1] All authors are employed at the National Center for Environmental Economics at the U.S. EPA. Questions or comments on the draft paper can be emailed to the authors at: Klemick.heather@epa.gov; Kopits.elizabeth@epa.gov, or Wolverton.ann@epa.gov.

[2] The authors would like to thank several people who provided support with coordinating and conducting focus groups and interviews: Tara Hamilton, Laurence O'Rourke, Pepper Santalucia, Micah Brill, William Prindle, and Beth Binns (ICF International); Jane Peters and Bobbi Tannenbaum (Research in Action); the Maryland Motor Truck Association; the California Trucking Association; the Iowa Motor Truck Association; Gloria Helfand, Angela Cullen, and Cheryl Bynum (Office of Transportation and Air Quality, U.S. EPA); and Alan Krupnick, Josh Linn, and Beia Spiller (Resources for the Future). Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Environmental Protection Agency.

I. Introduction

In 2011, the Environmental Protection Agency (EPA) and Department of Transportation (DOT) jointly introduced the first-ever regulations of fuel economy for medium- and heavy-duty trucks. EPA and DOT projected that not only would the regulations improve local air quality and reduce greenhouse gas (GHG) emissions by 270 million metric tons, but they would also save the trucking industry $50 billion in private fuel costs—a figure far exceeding the $8 billion estimated cost of the new technologies (EPA 2011). While 2011 was a time of historically high fuel prices, with diesel hovering close to $4 a gallon, high prices were hardly an aberration; after more than a decade of averaging less than $1.50 a gallon through the 1990s and early 2000s, on-highway diesel averaged well over $2 a gallon in every year since 2005 (EIA 2012). The elevated price of fuel in the years leading up to the regulations begs the question: Why were trucking companies not already adopting fuel-saving technologies even absent the mandate for improved fuel economy?

The "energy-efficiency paradox" is a term coined to describe the puzzling observation that households and firms often fail to adopt technologies and behaviors that outside experts estimate would save them money over the long term by reducing their energy costs (Jaffe and Stavins 1994). While the initial investment in a more efficient technology is typically more expensive than the alternative, net present value (NPV) calculations accounting for both upfront investment costs and projected future energy savings often find that such investments would pay off well within the lifetime of the product, assuming a market interest rate. Heavy-duty trucking is hardly the only example. Researchers have noted this paradox in cases ranging from household appliances to commercial buildings to passenger vehicles (e.g., Koomey and Sanstad 1994; Hausman 1979; Hassett and Metcalf 1993; Helfand and Wolverton 2011).

While much of the research on the energy efficiency paradox has focused on household consumers, several studies have examined firm behavior. Case studies of particular industries and technologies have noted evidence of the energy-efficiency paradox in a variety of commercial and industrial settings across industrialized countries (e.g., DeCanio and Watkins 1998; de Almeida 1998; Harris, Anderson, and Shafron 2000; Thollander and Ottoson 2008; Ryghaug and Sorensen 2009). Multi-industry econometric analyses, though even rarer, has also shown some support for the energy-efficiency paradox in businesses (Kounetas and Tsekouras 2008; Schlich and Gruber 2008). However; with a few exceptions, the literature examining firm decisions has focused on appliances, buildings, and industrial processes.

Researchers have posed a variety of hypotheses to explain the slow diffusion of energy-saving technologies. They include market failures like asymmetric or imperfect information about the new technology and related "learning-by-using" externalities; liquidity constraints limiting upfront investments; and the principal-agent or split-incentive problem, in which energy costs are borne by a "principal" but investment decisions are made by a separate "agent" (a common scenario among tenants and landlords) (Jaffe et al. 2004; Gillingham, Newell, and Palmer 2009; Levinson and Niemann 2004). Network externalities can also play a role in the diffusion of new technologies that become more useful or less costly the more widely they are adopted (Jaffe et al. 2004).[3] Research focusing on households has also highlighted behavioral failures—situations in which consumers behave in a way that is contrary to their own interests—as an additional explanation for the energy efficiency paradox. However, behavioral failures such as difficulties in making correct NPV calculations are expected to be

[3] Unpriced negative externalities associated with energy production such as pollution also undoubtedly play a role in suboptimal adoption of energy-saving technologies, but since the benefits of reducing pollution largely do not accrue to the user, we consider this issue to be orthogonal to the energy-efficiency paradox.

less relevant in explaining firm behavior because businesses that neglect to adopt profit-enhancing technologies would be expected to lose out in a competitive marketplace (Shogren and Taylor 2008). Empirical evidence has found support for principal-agent problems and imperfect information as contributors to an energy-efficiency paradox for firms in particular (Klemick and Wolverton 2013).

Market failures aside, some researchers have also pointed to factors not accounted for in typical NPV calculations that could decrease the benefits from adopting energy-saving technologies (Jaffe et al. 2004, Huntington 2011). These include ancillary costs of technology adoption, such as lower quality or higher maintenance costs (Jaffe et al. 2004). For example, some consumers have voiced complaints about compact fluorescent light bulbs (CFLs), including poor aesthetics and problems using them with dimmer switches (Broyodo Vessle 2009). Uncertainty about future energy savings could also make such investments less desirable (Sutherland 1991, Greene 2011). Analyses focusing on the average user of a product may also mask significant heterogeneity in energy use that could make adoption less beneficial for those that use less energy (Hausman and Joskow 1982). Actual energy savings under real-world conditions may fall short of engineering estimates (Metcalf and Hassett 1999). When these factors play a role, observed low adoption of energy-saving technologies may not reflect suboptimal decision-making, but rather a rational accounting of a larger set of factors than typically appear in NPV calculations.

Market failures and other factors excluded from NPV calculations are often discussed together under the general label of "market barriers" limiting investment in energy-saving technologies (Jaffe et al. 2004). However, because these explanations have different implications for energy policy we find it useful to distinguish between classic market failures and other potential barriers. From an economic perspective, market failures (including environmental externalities, which are not discussed in this paper) can be used to help justify policy approaches such as market-based instruments, information programs, and technology standards to encourage socially optimal levels of technology adoption. Policy can also appeal to psychology or present information differently to nudge users toward making beneficial choices (Sunstein and Thaler 2008, Alcott 2011b). However, if other factors that do not represent market failures contribute to low adoption, regulations can yield social costs for users that could at least partially offset the fuel-saving benefits associated with energy-saving technology. It is worth noting that various explanations for slow adoption of energy-saving technologies are not mutually exclusive; some or all could play a role in the market for any particular technology. For example, Anderson and Newell (2004) found that manufacturing plants that reject industrial audit recommendations with energy savings that outweigh upfront costs (typically with a payback in 2 years or less) typically did so for a mix of reasons such as high initial costs, lack of staff for implementation, cash flow issues, bureaucratic issues, process, equipment or facility change requirements, risk of a problem with equipment, and inconvenience.

This study contributes to the literature on the energy-efficiency paradox by providing insight into the investment decisions of firms in an under-studied sector. Using a qualitative case study approach, we focus on factors that affect heavy-duty truck tractor purchases. In particular, we conduct interviews and focus groups with representatives from 33 heavy-duty trucking companies. The interview and focus group approach allows us to speak directly to the individuals making technology adoption decisions to collect information that helps explain the slow adoption of some fuel-saving features in the heavy-duty trucking sector. It also allows us to ask questions specific to the various hypotheses for why an energy paradox may exist in heavy duty trucking so that we can parse which explanations seem most relevant.

In the next section, we provide greater detail on the trucking industry and why it presents a compelling case study for investigation of the energy-efficiency paradox. Section III describes our methodology, and

section IV summarizes basic data about the trucking firms participating in our study and factors they consider important when investing in a new tractor. Section V presents the main findings from the focus groups and interviews, distinguishing between market failures and other factors that affect tractor purchases among firms in our sample. This section also discusses participating firms' approaches to making payback calculations to decide whether to invest in a new technology. The final section discusses challenges and limitations in our approach and concludes the paper.

II. Heavy-Duty Trucking

Heavy-duty tractors (weight classes 7 and 8) appear to exhibit the characteristics typical of the energy efficiency paradox observed in other contexts. Studies point to potential technology options to improve efficiency in seemingly inexpensive ways. For instance, one study claims that fuel consumption from heavy-duty tractor-trailers could be reduced by 20 percent in 2012 and up to 50 percent by 2017 using existing technologies "while providing net savings for the owner based on lifetime fuel savings [that pay] for the incremental vehicle, operation, and maintenance costs" (NESCCAF et al. 2009). Similarly, analysis conducted for the EPA-DOT medium- and heavy-duty truck greenhouse gas and fuel economy standards observes that, "savings in fuel costs are *by themselves* sufficient to pay for the technologies over periods of time considerably shorter than vehicles' expected lifetimes" (U.S. EPA 2011).

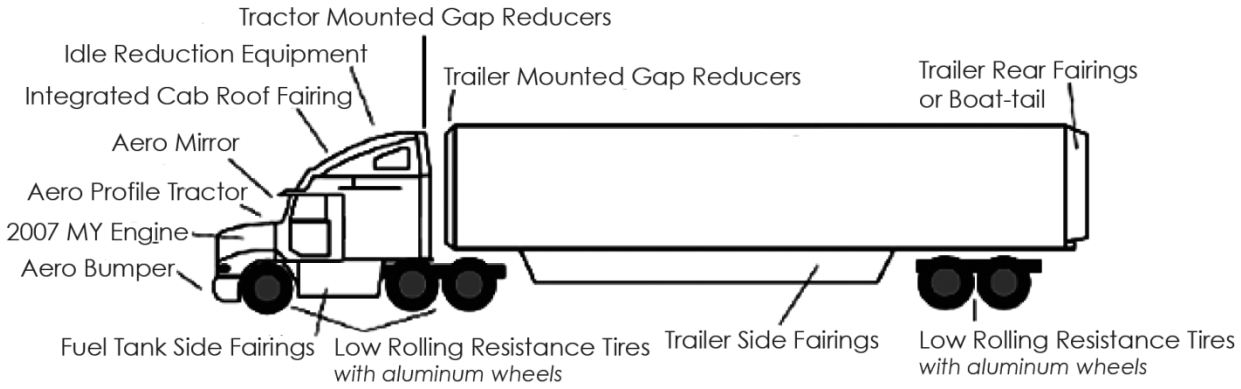
Some of the technologies that are recognized as having the potential to reduce fuel consumption at a negative cost for class 7 and 8 trucks include aerodynamic features to reduce drag and wind resistance (e.g. fuel tank and integrated roof fairings, aerodynamic bumper and mirrors), tires that reduce rolling resistance, and vehicle speed limiters (see Figure 1; U.S. EPA 2011, U.S. EPA 2013).[4] Auxiliary power units (an idle reduction technology), a new transmission system, automatic cruise control, and GPS routing technology also are identified as potentially cost-effective strategies to reduce fuel consumption for long-haul sleeper cabs (Carbon War Room 2012, U.S. EPA 2011; U.S. EPA 2013).[5] Single wide tires and automatic tire inflation are also mentioned as paying back "instantaneously" or over fairly short periods of time (ATRI 2007; U.S. EPA 2013).

The National Research Council (2010) points out, however, that the performance of fuel-reducing technologies depends on the duty cycle of the truck (e.g., load, road and weather conditions). For instance, a heavy-duty truck that gets 7.3 miles per gallon on flat terrain reduces fuel economy by 41 percent when traveling up a mild slope (Oakridge National Laboratory 2012). Because of the difficulty in controlling for these types of route-specific factors, the National Research Council (2010) identifies driver training as a potentially cost effective alternative to technology adoption for reducing fuel consumption.

[4] Installing an aerodynamic package that costs about $1,500 upfront could save $4,000 in fuel in the first year, on average. Likewise, a low rolling resistance tire that costs $200 upfront could save over $2,000 in fuel in the first year (U.S. EPA 2011).

[5] According to the U.S. EPA (2011), up to 25 percent of the fuel consumed by heavy-duty trucks at highway speeds is used to overcome aerodynamic drag. Idling a heavy-duty truck engine to use air conditioning or heat reportedly burns a gallon of fuel each hour (Oakridge National Laboratory 2012). A heavy-duty truck that drives 65 miles per hour instead of 55 miles per gallon is estimated to consume 20 percent more fuel (SmartWay website). Adding a combination of features –an auxiliary power unit, aerodynamics, advanced cruise control, and GPS routing technologies - is estimated to increase the cost of a new truck by $30,000 but "optimally" will save as much as $26,400 in fuel costs annually (Carbon War Room 2012).

Figure 1: Fuel Saving Truck Technologies



Source: NESCCAF 2009

Other attributes of the heavy-duty trucking industry also make it a good candidate for study. First, Class 7 and 8 trucks are responsible for about 75 percent of the fuel consumed by the medium and heavy-duty trucking sector (NESCCAF 2009). Second, fuel use is second only to labor as an expense for heavy-duty trucking companies engaged in a highly competitive market for transportation services (ATRI 2007; Federal Reserve Bank of Atlanta 2012). Thus, we expect firms to pay attention to these costs when making decisions. Third, the National Research Council (2010) observes that trucking is a sophisticated industry but still requires a payback of 18 months to 2 years on long lived equipment.

While heavy-duty tractors have been subject to emissions standards for engines for several years, fuel economy standards for heavy-duty trucking were only recently promulgated; the EPA-DOT regulations will apply to model years 2014 – 2018 and will be the first regulations on fuel economy in this industry. However, EPA has actively promoted fuel-efficient technologies in the trucking industry through its SmartWay voluntary program since 2004. As of 2013, SmartWay included well over 2000 truck carriers among its partners, suggesting that information about fuel-saving technologies is accessible to many firms. This situation allows us to investigate possible underlying reasons why opportunities that appear to be negative cost and are known by industry are not always adopted prior to the imposition of government mandates.

In this context, the question we study is: do trucking companies face market failures or are there other barriers to adopting technologies such as costs not easily captured in a present value calculation? The U.S. EPA (2011) posited several hypotheses for why the energy efficiency paradox may be observed for heavy-duty vehicles. There may be market failures such as lack of reliable information regarding the fuel economy of technologies. Split incentives could occur among those who buy the fuel and those who make tractor investment decisions, between owners and operators of the trucks, between the original and resale markets, or between different divisions within a large firm. [6] Network externalities, particularly regarding infrastructure for natural gas vehicles, also represent a potential market failure relevant to this industry. Other barriers to adoption may include hidden costs that have not been accounted for in the present value calculation such as a lower value being placed on fuel economy in the resale market when the vehicles are used for different purposes than originally intended, uncertainty with regard to future operating costs (maintenance and fuel), or the presence of adjustment or transaction costs.

[6] The NAS also points to possible "split incentives between owners and operators (e.g. trailers)," that we have limited ability to explore because of our focus on tractors.

There is little empirical literature to-date exploring the evidence for an energy efficiency paradox in the heavy-duty trucking industry. Vernon and Meier (2012) focus on the potential for split incentives between a trucking company and its drivers when the company pays the fuel costs: While the company may invest in fuel saving technologies, their effectiveness is influenced by driver behavior. The authors estimate that for almost 70 percent of the miles driven in the trucking industry, the drivers do not pay the cost of fuel or receive fuel-saving bonuses from their company. Based on interviews and surveys with owner-operators and trucking fleets, Roeth et al. (2013) identify five barriers to the adoption of fuel saving technologies for tractor-trucks and trailers in the on-road freight industry: lack of credible information about fuel savings that a particular company will achieve from a technology, uncertainty regarding payback of technologies (when the fuel savings will make up for the costs of adoption); capital constraints; reliability issues related to a new technology; and unavailability of fuel efficient technologies from preferred suppliers. Based on industry interviews, the Carbon War Room (2012) identifies a number of barriers to technology adoption in heavy-duty long-haul trucking: limited access to capital for owner-operators combined with high upfront costs, split incentives between the truck owner and the payer of the fuel costs, and lack of awareness about new technologies. As previously mentioned, we classify split incentives, incomplete information, capital constraints and network externalities as potential market failures, while we classify the remaining explanations as features that exist in many well-functioning markets but can nonetheless inhibit the adoption of certain technologies.

Our focus on companies with Class 7 and 8 tractors provides some uniformity across fleets with regard to available fuel saving technologies while still allowing for variation in factors such as fleet size, average distance traveled, road conditions, and types of product hauled. We exclude trailers from our discussion; while they are an important component of the fuel economy decision for heavy-duty hauling they are subject to a separate purchasing decision process with a distinct set of technologies that could be used to reduce fuel use. Likewise, we exclude vocational trucks – trucks that fall into weight classes 3 – 6 (e.g. fire trucks, cement trucks, delivery trucks) - because they are highly heterogeneous, they account for a much lower proportion of national fuel use, less information is available on what fuel economy technologies are feasible in this context, and they are typically used in very different circumstances than heavy-duty tractors.

Note that Roeth et al. (2013) relied on an extensive survey of heavy-duty owner-operators (drivers who own their own truck) to inform their conclusions regarding investment barriers. We largely exclude owner-operators from consideration in this study because they are harder to reach through interviews and focus groups. We only have information on owner-operators to the extent that the medium and large fleet managers discuss them; many hire owner-operators as drivers for their fleets when demand is high. Owner-operators also typically purchase trucks used, so their technology choice set is fairly different from the medium and large fleets that mainly purchase tractors new. Likewise, Roeth et al. only interviewed one medium and five large fleet operators for their study, a smaller sample than our own. Thus, while our study has some overlap with that of Roeth et al. (2013), it is largely complementary.

III. Methodology

A. Focus Group and Interview Approach

Given the limited literature and data available on how firms make capital investment decisions for energy-efficient technologies absent government regulation, we opt for a case study approach that relies on information gathered through focus groups and interviews. Focus groups and interviews have been used to gauge attitudes and opinions on a range of environmental and energy-related topics such as environmental practices when traveling (Barr et al. 2011); home and office building energy management (e.g., Sweeney et al. 2013, Peterman et al. 2013, Murtagh et al. 2013, Paetz et al. 2012, and Pellegrini-Masini and Leishman 2011); building design (Gul and Menzies 2012); regulation of wood smoke from home heating (Reeve et al. 2013); and carbon capture and storage (Shackley et al. 2004).

Focus groups and interviews have a number of recognized advantages over other data collection approaches (Frechtling and Sharp 1997). First, they allow the researcher to directly capture participants' perspectives on a given topic. Second, they permit in-depth exploration, allowing for direct follow up on statements of interest to further the researcher's understanding of particular perspectives and experiences. Third, they often can yield new insights beyond the scope of the researcher's preconceived hypotheses. Fourth, they allow the researcher flexibility in how questions are asked to reflect the unique circumstances and background of the participants. In-depth interviews are particularly appropriate for collecting detailed information on a complex or sensitive subject from busy, high-status participants. Focus groups are useful when the interaction of participants can result in a more nuanced, richer conversation than speaking to each participant individually. In particular, focus groups may highlight areas of agreement and disagreement among participants.

However, it is important to keep in mind the potential disadvantages of the interview and focus group approach (Frechtling and Sharp 1997). Interviews and focus groups are dependent on the facilitator's ability to moderate the discussion. While we relied on a professional facilitator, some of the issues we strove to discuss with fleet managers proved challenging. For instance, asking about the gap between payback and the amount of time a vehicle is in the fleet in a way that revealed insights into their thinking took several iterations. Information gathered via focus groups and interviews is also subject to biases common to research approaches that rely on statements from participants regarding their behavior instead of directly observing behavior. Flexibility in how questions are asked can result in inconsistencies across focus groups and interviews in what data are collected. For example, we did not always get complete answers for each of our hypotheses about the barriers to investment in fuel-saving technologies across all of the focus groups and interviews. Finally, recruitment of participants can be particularly challenging and is unlikely to result in a representative sample. We discuss this last issue in greater detail below.

We conducted six professionally facilitated focus groups, each approximately two hours in length, with representatives from small to medium-sized companies (companies with 10 – 500 tractors in their fleet). Fleets of this size represented about 32 percent of Class 7 and 8 combination trucks on the road in 2008 (ICCT 2009). We conducted another six one-and-a-half hour phone interviews with individual representatives from large national companies (those with more than 500 tractors in their fleet) where competiveness issues may have inhibited candidness in a group setting. About 24 percent of Class 7 and 8 combination trucks on the road in 2008 came from companies of this size (ICCT 2009). We varied these focus groups and interviews by the company's main line of business, trip length, and geographic region. The company names of participants were known to our contractor to avoid duplication in recruitment

but were otherwise masked to protect the confidentiality of participants. We conducted the interviews and focus groups between April 2012 and February 2013.

By varying participants based on whether trucking is the main line of business we are able to investigate two types of business investment decisions. The first type pertains to reticence to invest in seemingly cost-effective equipment or technology related to the direct line of business in which a company engages. In the context of trucking, these are the "for hire" trucking fleets that make money by shipping others' goods. For-hire fleets made up about 32 percent of the interstate trucks on the road in 2011 (American Trucking Association 2011). The second type pertains to investment decisions that could lower expenses for the firm but are well outside the main line of business. So-called "private" trucking fleets meet this criterion. These are businesses whose main source of revenue is retail or manufacturing of particular goods but own a fleet of trucks to haul their products between warehouses and stores. About 53 percent of the interstate trucks on the road in 2011 were private carriers (American Trucking Association2011). We limited our discussion to tractors, even though the characteristics of the trailers certainly affect a truck's overall fuel economy.

Focus group participants were recruited through collaboration with state trucking associations. We reached out to several associations to identify those that would be willing to recruit fleet managers, chief operating officers, or directors of transportation among their members. While a number of state trucking associations expressed interest in partnering with us, those that ended up participating are not a random sample of the industry; they are likely more interested in energy and technology issues. To decrease the heterogeneity of participants within each focus group, we separated fleets into broad categories based on typical trip length and main line of business. We defined short/regional-haul fleets as those primarily taking day trips with the majority of these trips within approximately 250 miles,[7] while long-haul fleets specialize in multi-day trips using sleeper cabs. In Maryland we conducted one short/regional-haul for-hire (MD SRH FH)[8] focus group and one short-regional haul private (MD SRH PR) focus group. In California, we conducted one short/regional-haul private focus group (CA SRH PR) and one for-hire group that mixed regional- and long-haul fleets (CA MG FH). In this case, the mixed group consisted mostly of regional-haulers. In Iowa, we conducted one long-haul for-hire (IA LH FH) group and one for-hire group that mixed regional- and long-haul fleets (IA MG FH). Unlike for California, the mixed group in Iowa consisted mostly of long-haul companies.

Interview participants were recruited through a combination of state trucking association contacts and industry expert contacts. As with the focus groups, participants volunteered their time. As such, individuals we interviewed also do not reflect a random sample. We conducted interviews with one short/regional-haul for-hire firm, two long-haul for-hire firms, and three short/regional-haul private firms. To ensure we did not only include trucking companies that are industry leaders with regard to adoption of fuel economy technologies, we recruited both SmartWay and non-SmartWay partners to participate in the focus groups and interviews.

[7] For California, we considered fleets primarily operating in-state to be short/regional-haul (trips within about 450 miles) because of feedback we received from the association that day-trips are often longer among their members.

[8] Throughout the paper, we label references to each focus group according to state in which it was conducted (CA, IA, MD). Interviews are labeled numerically by the order in which they were conducted. Focus groups and interviews are also identified by trip length (long-haul (LH), short/regional haul (SRH), or mixed group (MG)); and business type (for-hire (FH) or private (PR)).

We purposely over-recruited because of the possibility of attrition between recruitment and the focus group events. Our goal was to have four to six participants in each focus group. In general we achieved this goal: one focus group only had three participants but of those remaining, two had four participants; two had five participants; and one had six participants. About 63 percent of the 43 managers recruited ultimately participated in a focus group. There were no obvious patterns with regard to likelihood of participation across private versus for hire or short/regional- versus long-haul fleets. However, managers of fleets with fewer than 20 tractors were much less likely to show up for the focus group: 58 percent of recruits with fewer than 20 tractors ended up not participating compared to 29 percent of managers of larger fleets. Intuitively, this makes sense. Smaller companies also are likely to have smaller management teams, making it more difficult for them to be away from the office for extended periods of time. This bias in our sample confirms our limited ability to speak to potential barriers faced by owner-operators or smaller trucking fleets.

B. Moderator's guide

To guide the focus groups and interviews we designed a moderator's guide and an accompanying questionnaire about fuel saving technologies (see the Appendix for copies of these materials). We used a semi-structured funnel design, starting with broad questions about how companies make investment decisions for heavy-duty tractors before asking narrower questions about the specific role fuel economy plays in decision-making. We encouraged the facilitator to begin with open-ended questions but provided prompts to facilitate the discussion as needed. The ordering and specific wording of the questions evolved slightly over time to reflect what we learned from previous focus groups and interviews.

The moderator began each focus group and interview with a broad discussion. She asked participants to list the top factors they considered when purchasing a tractor for the fleet and whether purchases are made on a set cycle or an as-needed basis. She then asked participants to walk through the process of purchasing a tractor and discuss the types of information collected to inform the purchase decision. Finally, participants explained whether this process differs for new features they have not previously tried, for leased versus purchased tractors, or for new versus used tractors.

In the next section the moderator asked participants to think about features or specifications on a recently purchased tractor that were included with the goal of improving fuel economy. She asked participants why particular features were appealing to adopt, whether other fuel economy improving features were less appealing and reasons for non-adoption. She then asked about key factors that might affect how fuel economy is considered when purchasing tractors (for instance, reliability, safety, access to financing, additional costs) and whether they are reflected in a return on investment (ROI) or payback calculation. Because we did not want to rule out factors that we did not think of ourselves, we instructed the moderator to not prompt the discussion unless a particular factor that was expected to be important was not suggested by the participants themselves.

The last section of the focus group discussion was keyed off a questionnaire that participants were asked to fill out during a brief break in the focus group (or in advance, in the case of interviews). The two page questionnaire asked basic questions about purchases and included a detailed list of features and technologies that can be added to the tractor to potentially improve fuel economy. We developed the list of strategies based on a review of the information available on known fuel-saving technologies predicted to result in net cost savings over a relatively short period of time, on average (ATRI 2007; NESCCAF 2009, NRC 2010, U.S. EPA 2011, Carbon War Room 2012, U.S. EPA 2013). Participants were

asked to indicate whether they had tried a particular feature and whether they would consider using it in the future. The moderator used this information to ask participants about their experiences with particular technologies. Finally, using as an example a technology known to have a short payback, the moderator asked whether participants make similar calculations, and ask why some technologies are not being adopted in spite of what looks like a very short payback (or high ROI).

C. Compiling results

To compare the results from the focus groups and interviews, we performed detailed content analysis where we matched transcript text to a pre-defined set of codes (Radcliff and Best 2005). Based on an initial read of the transcripts, we generated a set of codes for each question in the moderator's guide. We then tested the codes on one interview and two focus group transcripts by having two individuals independently code the same transcript and then compared them for consistency. The pre-testing of the codes allowed us to adjust them as appropriate, combining some categories and further refining others. Once the set of codes was finalized, we carefully read through the transcripts for each focus group and interview and systematically applied the codes. We used the coded transcripts to assemble a spreadsheet summary to identify patterns across focus groups and interviews.

IV. Participant Characteristics and Purchase Decisions

Our final dataset consists of transcripts involving 33 trucking companies: six focus groups involving 27 companies (with three to six participants per focus group) and six one-on-one interviews (each representing one company). Table 1 summarizes key characteristics of the participants, based on their responses to the screener questions that were asked prior to the focus group or interview. (A copy of the screener is provided in the Appendix.) General factors that focus group and interview participants highlighted as important when making tractor purchase decisions are summarized in Table 2.

As explained in Section III, the interviews were conducted with larger national trucking firms that had at least 500 tractors, while small to medium sized companies were recruited for the focus groups. Fleet sizes in the focus groups ranged from 10 to 500 tractors, with most participants having fewer than 100 tractors, and the fleet size of the interviewees ranged from 501 to 11,000. About two-thirds of the companies were short/regional-haul (i.e., primarily making day trips). The average annual distance traveled per tractor ranged from 20,000 to 250,000 miles/year, with over 70 percent of the participants reporting between 70,000 and 120,000 miles/yr. Over two-thirds of the sample consists of for-hire trucking firms, remaining participants manage and operate private fleets.

Nearly all the participating companies purchased their tractors new rather than on the secondary market. The bigger firms tended to hold on to trucks for at least seven years. Many participants who reported a shorter average truck life (e.g., five to seven years) were in focus groups in which at least some leased their tractors. The focus group responses were mixed as to whether tractors were replaced on a set cycle or an as-needed basis. Leasing tended to occur on a set cycle. Decisions to replace a truck as-needed were often based on a combination of age, mileage, and reliability. As one participant explained: *"You look at the piece of equipment and go, 'Are you having a lot of issues with it?' …maybe it really wasn't that old or maybe it didn't have the number of miles you were trying to hit, but you've had a lot of repair issues, so then it's going to get replaced"* (IA LH FH).

Table 1. Participant Summary

		Number of participants	%*
Total number of participants (focus groups plus interviews):		33	
Short/regional (i.e., majority of the trips within 250 miles)?		22	67%
At least 90% of tractors purchased new (vs. used)?		30	91%
Average truck life:	3-5 years	7	21%
	5-7 years	13	39%
	7-10 years	10	30%
	>10 years	3	9%
Fleet size (number of tractors):	10-50	13	39%
	51-100	9	27%
	101-500	5	15%
	501-1,100	4	12%
	1,100-11,000	2	6%
Average single trip distance (miles):	15-90	4	12%
	91-300	14	42%
	301-600	12	36%
	601-1,100	4	12%
Annual distance traveled per tractor (miles):	20,000-60,000	5	15%
	60,001-90,000	12	36%
	90,001-120,000	13	39%
	120,001-250,000	3	9%
Type of freight service:	Truckload	25	76%
	Less than truckload	8	24%
	Tanker	4	12%
	Refrigerated loads	9	27%
	Other	10	30%
Type of goods transported:	general commodities, dry freight	17	52%
	food products (including fresh and frozen)	12	36%
	construction materials, machinery (including farm, lawn and garden)	6	18%
	liquids (e.g., chemicals, fuels)	3	9%
Private carrier (vs. for-hire)?		10	30%
EPA SmartWay partner?		11	33%

*Percentage based on total number of participants. For example, 67% of respondents reported that the majority of their company's trips are within 250 miles.

Some companies stated that they have moved away from purchasing on a set cycle both because the cost of new tractors has gone up and tractors last longer than they used to, which means a company can get more miles out of them. One participant summarized their strategy as: "*We're just trying to use the equipment to the best of our ability for the longest time we can before we have to replace them*" (IA LH FH). A company that leases its trucks also noted they hold onto their tractors for "*anywhere from three to eight… depending on the mileage"* (MD SRH PR).

Recently, when upgrades occur has been affected by the recession and general business outlook. One participant in the Iowa long-haul focus group stated that the recession meant hanging onto trucks longer, and if he misses the optimal window for sale to the secondary market then he is more likely to hang onto a reliable truck for as long as possible (i.e., it will have little resale value if the window is missed). Some companies in the California focus groups also mentioned that regulation affected the timing of their truck purchase decisions. We will return to the role of regulation in Section V.

Across the sample of focus groups and interviews, there was some variation in the types of goods hauled, but over half of the firms we talked to had carried at least some dry freight/general commodities and over 75 percent of all participants had full truckload service. About a third of the companies are SmartWay members, with a good mix across both focus groups and interviews.

Important factors in truck purchases. Fuel economy was recognized by many of the participants in all six focus groups and all of the interviews as a top factor in tractor-truck purchase decisions (see Table 2). One participant stated it this way: *"I'd say [we put] probably 150,000 miles a year on the trucks we run, so fuel economy is big;"* a small change in fuel mileage could mean *"a lot out of the bottom line"* (MD SRH PR). In contrast, a few of the short/regional-haul fleet managers stated that fuel is not a large expense for them since they put so few miles on their trucks annually. They had *"bigger fish to fry"* than investing in features or technologies that result in a small fuel economy improvement (INT #5 SRH PR). Reliability and maintenance issues were also mentioned as top factors by participants in all of the focus groups and interviews. *"It's all about reliability"* according to one of the fleet managers we interviewed (INT #3 LH FH). ICCT (2013) also found that reliability is of paramount importance.

Not surprisingly, upfront cost was mentioned in five out of six interviews and focus groups as a top factor in purchase decisions. In fact, participants in several groups stated that upfront cost was the single most important factor. While warranty was also frequently mentioned as a top factor to consider when purchasing a new tractor-truck (in five out of six focus groups and interviews), there was substantial heterogeneity in opinions about its relative ranking. We also heard several different explanations for why warranty is less important: For instance, one participant stated that since everyone offers a warranty, it doesn't matter (INT #6 SRH PR). Another participant stated that *"the best warranty in the world is not worth anything if the truck is not running"* (INT #3 LH FH).

While driver preferences also were mentioned in most of the interviews and focus groups as an important factor for business operations, many in these groups acknowledged that it does not rank among the top three factors affecting tractor investment decisions. One long-haul fleet manager stated that the truck is the driver's *"home away from home. There are certain brands of trucks that have a smaller living space, and we take that into consideration"* (IA LH FH). Another participant had very low driver turnover and "*attribute[s] part of that to the fact that they're driving what [the drivers] perceive to be the best"* (IA MG FH). A manager of a large short/regional-haul fleet stated that *"generally, the drivers that are the most proud of their trucks take the best care of their trucks. Because we keep our trucks so long, that is a factor"* (INT #5 SRH PR). That said, the groups of participants that did not mention driver preferences as important consisted of private short/regional-haul fleet managers. Given that driver turnover tends to be much higher in for-hire fleets than in private fleets (90 percent vs. 10 percent), the desire to entice for-hire drivers to stay by accounting for their preferences makes sense (Roeth et al. 2013).

Weight was also frequently mentioned as a top factor by focus group and interview participants. Because of weight limits on roads, fleets were always trying to *"shed weight"* so they can haul more goods (MD SRH PR, IA LH FH). Of the four sets of participants that made no mention of weight, three consisted of private short/regional-haul fleet managers. Resale value was only mentioned by one of the large companies we interviewed, but was discussed as a top factor for tractor-truck purchases in four of the six focus groups. Three of these focus groups consisted of managers of long-haul fleets.

Table 2: Main Factors in Purchase of a New Tractor-Truck

Factors mentioned by participants	Focus groups	Interviews
Fuel economy	6/6	6/6
Reliability/maintenance	6/6	6/6
Upfront cost	5/6	5/6
Driver preferences	5/6	5/6
Warranty	4/6	6/6
Weight	5/6	3/6
Resale value	4/6	1/6
Safety	2/6	2/6
Fuel price	2/6	1/6
Dealer relationship	3/6	0/6
Customer	1/6	2/6
Regulation	2/6	0/6
Expected use	1/6	1/6

Less consistently important but occasionally mentioned as a top factor for tractor-truck purchase decisions were safety, fuel price, dealer relationship, customers, regulatory requirements, and the expected use of the tractor. The focus groups that mentioned dealer relationship and fuel price as important were mainly made up of long-haul fleet managers. A short/regional-haul fleet manager we interviewed disagreed. He stated that *"the price of fuel is not relevant. It's the fuel economy that's relevant."* It is *"very different if you're talking about your car [saving] one tenth of a mile per gallon traveling 12,000 miles per year versus a fleet of 9,000 trucks [saving] one tenth of a mile per gallon traveling 57 million miles a month. Almost any fuel economy improvement, regardless of the price of fuel, is significant"* (INT #1 SRH FH).

Participants also offered mixed responses about the importance of customers in affecting tractor purchases. In the case of for-hire fleets, the customer would be the businesses contracting for a product to be delivered; for private fleets, the customer could either be the retail outlet receiving the delivery or the final consumer of the product. Two of the three sets of participants that mentioned customers as a top factor in tractor purchases managed private fleets, though another private fleet manager said customers do not factor into the company's purchase decisions because they never see the truck: the company makes nighttime deliveries (CA SRH PR). However, even in this instance the participant stated that: "*Every one of us is concerned about image. When our guys are driving up and down the road, you have a big huge billboard you're dragging behind you, and it has the company name on it and that's very important"* (CA SRH PR). Participants in the for-hire focus groups rarely mentioned customers when discussing top factors affecting investment decisions. One participant offered the following explanation: "*We're… not an image outfit. When you're going out there in those back hills in the dirt and the rocks and everything else, nobody cares what your truck looks like. Can you get up that mountain? That's what we want to know"* (CA MG FH).

Table 3: Barriers to investment in fuel-saving tractor technologies: market failure hypotheses

Potential barriers to investment	Mentioned as barrier by participants		Sample quotations
	Focus group	Interview	
Imperfect information	6/6	6/6	*"...a huge problem in the industry right now is just having a good, reliable source of test data that you can extrapolate to your own operations."-INT #2 SRH PR*
Split incentives - resale market	3/6	4/6	*"A lot of people on the secondary market use [the tractors] for construction or farming and they want the traction, so [FE technology] could hurt...So, you know, there's a little tradeoff." –INT #3 LH FH* *"Common wisdom would say that that tractor should command a premium with a buyer that's interested in fuel economy, but the aftermarket just hasn't proven that yet." –INT #2 SRH PR*
Split incentives - driver	6/6	4/6	*"It's being able to control or teach the driver to have the best possible habit…There are systems out there that actually train a driver." – IA LH FH*
Split incentives - trailers	2/6	0/6	*"I have no control. I pull other people's trailers." -IA MG FH*
Liquidity constraints	0/6	0/6	*"They're [banks and dealers] just knocking on your door to finance you."-IA MG FH*
Network externalities	6/6	6/6	*"But the biggest issue with [natural gas] still is they don't have the infrastructure. You can't go out to a fuel station that sells diesel and say, 'Fill me up with LNG.' It's just not there." -CA MG FH* *"I can't imagine trying to get a super single [tire] in some places in West Virginia at 2;30 in the morning." – MD, SRH FH*

Note: each focus group is labeled according to state (CA, IA, MD); trip length (long-haul (LF), short/regional-haul (SRH), or mixed group (MG)); and business type (for-hire (FH) or private (PR)). Interviews are labeled numerically in the order in which they were conducted.

V. Main Findings about barriers to investment in fuel-saving technologies

A. Market Failures

We now turn to one of the core questions motivating our discussions with trucking firms: Do market failures pose a barrier to adoption of technologies that would improve truck fuel economy? Table 3 summarizes the findings from the focus groups and interviews regarding the main market failure hypotheses: imperfect information, split incentives, financial constraints, and network externalities. It also provides a few illustrative quotations demonstrating that while some appear to apply, others do not. For instance, all of the focus groups and interviewees discussed imperfect information as a barrier to adoption of fuel-saving technologies. However, no focus group or interviewee thought liquidity constraints acted as a barrier. We discuss each of these issues in-depth below.

1. Imperfect Information

One hypothesis that could explain the slow adoption of fuel-saving tractor features is that trucking firms have imperfect information about new technologies. If information about the fuel savings from a new technology is costly to acquire, trucking firms may have less incentive to invest. The technology adoption literature has noted the potential for knowledge externalities to create a market failure relevant to energy efficiency (Jaffe, Newell and Stavins 2005). Imperfect information could lead to inefficiencies in the market for new tractor features if the knowledge about fuel savings (and other aspects of performance like reliability) gained by a firm from trying out a new technology is also useful to other fleets, sometimes termed "learning-by-using" externalities.

As a first step in understanding the role of information barriers in tractor investment decisions, we asked participants how they gather information about new technologies and their expected fuel savings. Table 4 provides a summary of responses.

Table 4. Information sources fleets use and trust

Info sources mentioned by participants	Focus groups	Interviews
Manufacturers/dealers	6/6	6/6
In-house testing	6/6	5/6
Drivers	6/6	5/6
Peers	6/6	3/6
Trade publications	6/6	2/6
Conferences & trade associations	5/6	2/6
Regulators/SmartWay	2/6	0/6

Manufacturers or dealers were mentioned as a source of information about new tractor technologies by participants in every focus group and interview. While several participants mentioned that they trust

manufacturers' and dealers' views on whether a particular technology is likely to save fuel in a qualitative sense, most agreed that their quantitative estimates of fuel economy were not reliable. One participant described manufacturer fuel economy estimates as *"...nothing more than a mathematical calculation. It is not real-world, and we find very consistently that what the OEMs [original equipment manufacturers] report versus what we see in the real world is very different. So we discount that pretty heavily"* (INT #1 SRH FH). Thus, information available from manufacturers and dealers may not be sufficient for a firm to judge whether a new technology is worth adopting in its fleet.

Peer fleets and in-house testing were two of the most trusted sources of information about fuel savings from new technologies. Participants valued both types of sources for providing information about fuel use under real-world conditions. While several focus group participants and a few interviewees mentioned conferences and trade associations as a way to connect with peers, informal peer networks were just as, if not more, important. One focus group participant explained, "*We do not rely on the [manufacturer's] estimates. [We] get a general idea of the specification that we're proposing to purchase but we don't count on it because we know that how we run the equipment has a much bigger impact….. And we try to verify with references. Who's running like equipment? Do you mind if I talk to them? A couple of quick phone calls and how they run it, and we can get an idea of how accurate those manufacturer fuel mileage statements are" (INT #5 SRH PR).* Smaller and medium-sized fleets particularly valued information from larger fleets, as well as trade publications; for example, *"I don't always believe the manufacturer or the dealers. I believe the ones that have experience – from the bigger fleets, and the* Transport Topics*, or some of the other magazines too"* (IA MG FH). Involvement in EPA's SmartWay program and several industry organizations was mentioned by one interviewee as an important way to network with other fleets (INT #2 SRH PR).

Despite ready access to information from peers, many firms still stressed the need for in-house testing before adoption of a new technology throughout the fleet. As one participant put it, "*We never just all of a sudden say, 'Oh, yes, let's put those on 7,500 trucks.'"* Instead they *"test a few to start with to make sure there's a good fit"* (INT #4 LH FH). Another participant emphasized, "*We trust our own testing more than anyone else's*" (CA MG FH). Some participants, even among the smaller firms, described sophisticated approaches to assess new features, using the same driver, route, and load type to conduct test runs to compare a new versus existing technology while holding a number of key factors constant. Others did more limited piloting to gauge reliability before wide adoption. However, not all participants could conduct their own testing due to limited resources. While opinions differed across participants on the difficulty of conducting in-house testing, one interviewee described the challenges associated with gathering fleet-specific fuel economy information:

> *"It's challenging for fleets to figure out what gets the best fuel mileage, particularly if you're dealing with small samples, because you've got driver influence, the duty cycle influence – this tractor kind of does this because this driver does this. Unless you've got 20 or 30 or 40 in two groups and you run them in the same business cycle, then you can figure out – oh yes, these get a 10th or two better. And that allows all these companies to kind of co-mingle and nobody knows who's got the best fuel economy. Although sooner or later it kind of tells"* (INT #3 LH FH).

While in-house testing was used by firms of all sizes in our sample, the larger firms placed less emphasis on peers, conferences, trade shows, and trade publications such as *Transport Topics*, possibly because their in-house resources precluded the need for outside information. Drivers were mentioned as an important information source in all focus groups and in five out of the six interviews. Drivers typically

provided feedback about truck performance and reliability rather than fuel economy specifically, though some firms relied on particular trusted drivers to test out new truck features. Participants in both California focus groups mentioned the EPA SmartWay program as a potentially useful source of information about fuel-saving technologies, even when they elected not to become a member. However, participants in the California focus groups were skeptical of information provided by the California Air Resources Board (CARB). A few participants also mentioned telemarketers and aftermarket product vendors but were always highly skeptical of the information provided; more than one participant referred to their products as "*snake oil*" (CA MG FH; INT #4 LH FH, INT #6 SRH FH).

Once participants adopted a new technology, tracking fuel economy was relatively straightforward. Many firms installed onboard monitoring systems that collect a wealth of variables such as mileage, speed, idling, hard breaking, and fuel usage. One participant noted, *"I get an engine diagnostic report that gives me a graph of fuel economy, vital signs, and then also what they call high resolutions"* (IA LH FH). Another participant explained, *"I keep 100 percent track of everything that's going on. We write it down. It goes into a computer system... I know what it's running for fuel – every single detail..."*(IA MG FH). Even firms without onboard recording systems often closely tracked fuel usage due to fuel tax reporting requirements for firms that operate across multiple US states or Canada imposed by the International Fuel Tax Agreement.

Focus group participants and interviewees were also well informed about the availability of emerging technologies to save fuel. All participants were familiar with every technology listed in Table 7.

While participants had access to a variety of information sources about new technologies, many highlighted a lack of knowledge about how new technologies perform under real-world conditions in their particular firms. As one interviewee noted, *"...a huge problem in the industry right now is just having a good, reliable source of test data that you can extrapolate to your own operations"* (INT #2 SRH PR). Although the use of peers as an information source implies that knowledge about fuel-saving tractor technologies has a public good component in the trucking industry and could therefore by underprovided by the market, the wide heterogeneity among trucking fleets limits the usefulness of industry-wide average information. A focus group participant elaborated, *"...it isn't like buying a car where you walk up to the window and it says, you know, your city mileage is X and your highway mileage is X. .... that's all dependent upon driver, road condition, what kind of load you're pulling. There's so many variables"* (MD SRH FH).

In fact, the trucking industry epitomizes the passenger vehicle fuel label qualifier "your mileage may vary." Factors such as weather, terrain, traffic, speed, trip length, and idling time can vary tremendously across companies and routes. Aerodynamic fairings perform differently on tanker trucks than refrigerated trucks and for short versus long haul trips. Tire fuel economy depends on temperature and road surface. A focus group participant explained:

> "*We have trouble because of our niche market. The sales folks want to come out and talk X fuel mileage or Y life of something. And until we've actually seen it run in our niche market or our segment of the industry, I'm obviously very, very skeptical. Because, again, a truck pulling a van or a reefer [refrigerated truck] can maybe achieve 7.4 or 7.5 or 7.6, but pulling the freight that we pull, we're just not going to get that" (IA LH FH).*

This type of industry variation suggests that beneficial knowledge spillovers about fuel savings from new technologies are limited. Firm-specific fuel economy information about new technologies is likely to be

most informative to other companies in the same segment of the industry and even then may not be sufficient to make an investment decision. An interviewee summarized, *"Everybody at the end of the day goes back to, 'What is it doing in my fleet?'"* (INT #1 SRH FH). We return to the issue of fleet heterogeneity in section V.B.

The need for company-specific information means that firms may need to incur significant transaction costs in the form of in-house testing to accurately estimate the fuel savings from a new technology. A focus group participant confirmed that this type of research can delay widespread adoption of new technologies: "...*you could have the greatest technology today and it won't be on my fleet for three years, because I'm going to validate what's that savings, what's the cost*" (CA SRH PR). In sum, imperfect information contributes to slow adoption of new fuel-saving technologies for trucking firms in our sample. However, due to heterogeneity among firms, the positive externalities associated with learning-by-using are likely to be small relative to the private benefits to the firm.

2. Split Incentives

Lack of information can manifest itself in a second type of market failure referred to as a principal-agent or split-incentive problem. Split incentives occur when "the principal" - for instance, the person at the trucking company tasked with deciding what investments to make to save fuel such as a particular fuel efficient feature on a newly purchase truck, cannot ensure that "the agent" - in this example, the driver - is acting in the company's best interest by using the technology appropriately . When the agent does not fully understand what fuel-saving features are available or fails to incorporate the implications of their actions for the cost of fuel into his or her decisions, the principal may not be able to recoup the costs of the investment and therefore will likely under-invest in fuel saving features, resulting in a market failure (Jaffe and Stavins 1994; Gillingham et al. 2009).

Split incentives could be present in several areas of the heavy duty trucking sector. If the resale market does not value or recognize fuel economy features on vehicles, then the potential return on investment for the first owner is truncated. Likewise, if the drivers of the trucks do not pay directly for fuel or do not have incentives to incorporate fuel consumption into their driving choices, then investment in fuel-saving features by truck owners will be underutilized (Vernon and Meier 2012). There may also be a lack of coordination between the person or divisions at the company that negotiates fuel prices and those that purchase the trucks so that fuel consumption tradeoffs of particular performance- or safety-enhancing features are not fully incorporated into purchase decisions. Finally, the NAS (2010) and Vernon and Meier (2012) both point to split incentives between the tractor and trailer in freight transportation. These two pieces of the truck work in tandem to determine fuel economy, but often a tractor is pulling another company's trailer.

How the Resale Market Values Fuel Saving Features. The role of the resale market in decisions regarding technology adoption was mixed among focus group and interview participants. The managers of short/regional-haul private fleets we interviewed stated that the resale market had little influence on their purchase decisions because they *"run the trucks into the ground"* and then scrap them (CA MG FH, INT #6 SRH PR). When the same owner had the truck over its full lifetime (10+ years) there was no opportunity for split incentives between the original and resale markets. However, the short/regional-haul private fleet managers that participated in focus groups did not echo this perspective. Several participants of all types –short/regional- and long-haul; private and for-hire - indicated that their companies determine how long to hold onto a truck (four to seven years) based on the strength of the

resale market. They kept them longer when the resale market was weak and the truck posed few maintenance and repair concerns, but tried to resell them before reliability became an issue.

Of the participants who sold tractors into the secondary market, several indicated that they may select certain features that are valued in the resale market when purchasing a new tractor. However, these features were rarely related to fuel economy. For many of the participants, the lack of value placed on fuel-saving features in the resale market often was unrelated to lack of information or uncertainty about potential savings –indications of potential split incentives. Instead, they often sold the tractors into markets where they are put to potentially very different uses than those for which they were originally purchased. As one long-haul for hire carrier put it: *"A lot of people on the secondary market use [the tractors] for construction or farming and they want the traction, so [FE technology] could hurt...So, you know, there's a little tradeoff"* (INT #3 LH FH). Participants also reported that many of their used trucks were sold into international markets where they may or may not be put to similar uses. In these cases, there is a valid reason why secondary users do not value fuel saving attributes.

Some participants observed that second-hand tractor buyers put a premium on fuel saving features due to higher fuel prices. One for-hire participant stated, *"Everybody is looking for fuel mileage. They don't want the big, long nose [trucks]. It's no longer like it used to be"* (IA MG FH). This resale premium was particularly likely for trucks that were on the younger side, as these trucks were often put to similar uses, and for trucks purchased by owner-operators in California due to stringent regulatory restrictions. That said, a few participants pointed to evidence of split incentives for owner-operators in the resale market. According to one private short/regional-haul fleet manager, owner-operators have misperceptions about some technologies: *"The guys that are buying used trucks are a lot less sophisticated than the ones buying new ones, and so there's a big knowledge gap on what works and what doesn't"* (INT #2 SRH PR). A large long-haul firm has experience with both perspectives, noting

> "*the secondary market is very much looking at a truck that is more efficient and more competitive and lower cost of ownership for them,"* but at the same time, *"the secondary market might not be ready for something you put on that truck, such as automated transmissions…, such as wide-based tires. They're a deduction… in the used market. So, not everything is totally accepted in the secondary market. It would depend upon who that secondary buyer is. You might have something that works very, very well for you, but that other guy doesn't want to buy it. So now you're going to take a deduct[ion] on it because you deployed some of this technology on there"* (INT #4 LH FH).

Role of Driver in Determining Fuel Economy. For most focus group and interview participants, the drivers are an important determinant of fuel economy and can enhance or detract from the effectiveness of fuel saving technologies. According to one fleet manager we interviewed, *"the driver controls about 40 to 45 percent of the overall fuel economy of the vehicle"* (INT #1 SRH FH). Because drivers do not control trucking investment decisions, this role creates scope for split incentives. Several participants mentioned that they had driver incentive programs to increase fuel-saving behavior. For instance, if drivers reduce idling time or stay out of first gear a company may offer a cash bonus, allow them to drive slightly faster or provide them with a gift certificate as a reward. Such incentives may provide a mechanism for fleets to reduce the split-incentive problem between firms and drivers.

The choice of fuel saving technology also was affected by driver behavior. A large fleet manager we interviewed stated that his company considers how easy a new fuel saving technology is for drivers to use before adoption. His aim was to avoid a situation where "*a lot of extra effort*" was required for

proper operation of the truck. *"There are things you can put on trucks potentially...that require a lot of change from the driver's standpoint"* (INT #2 SRH PR). For this reason, participants reported that driver training is often needed when adopting new technologies to ensure trucks get the expected fuel economy. For example, low rolling resistance tires require that drivers slow down. Auxiliary power units (APUs) only deliver fuel savings if the truck and APU are not run simultaneously. As a result, investments in technologies that require substantial driver behavioral change *"may not be worth it in the grand scheme of things compared to an option that…does not require the operator of the vehicle to do anything drastically different"* (INT #2 SRH PR).

While some focus group participants felt that *"training the driver is the best way to save fuel"* (CA MG FH), others rely on technology to minimize the driver's effect on fuel use. For instance, cruise control, vehicle speed limiters, and automatic transmissions allow the technology to control some aspects of the truck's performance, which reduces heterogeneity across drivers with regard to fuel economy and makes training less necessary. One participant stated, "*We're spec'ing [the trucks] with automatic transmissions…because [they] will shift it when you want it to every time as opposed to the driver who may be taking it up an extra 300 RPM and making that shift when you don't want him to"* (CA SRH PR). Since most fleets have trucks that vary in age and available features, some participants reported that they allocated trucks with automatic transmission or cruise control to more fuel-intensive drivers, while more experienced drivers *"who know how to drive a truck"* were given manual transmission (MD SRH PR). Other types of technologies allow managers to closely monitor fuel economy and can provide drivers with valuable feedback to help improve their performance. While Roeth et al. (2013) found that for-hire fleets generally preferred fuel-saving technologies that require little from the driver to function properly and private fleets often chose technologies that require more driver involvement, several private fleet managers that participated in our focus groups and interviews expressed a preference for technology-based solutions that require little change in driver behavior.

Other Potential Split Incentives. There is minimal evidence of underinvestment due to lack of coordination within the firm in our sample. Most participants that are responsible for purchasing trucks also are responsible for the fuel expenses. A fleet manager from one firm described coordinated decision-making involving a vice president, management of logistics and maintenance, and drivers in the discussions of truck purchases.

We did not prompt the issue of split incentives between tractor and trailer owners in the moderator's guide due to our focus on tractor purchases. However, tractor-trailer split incentives, particularly with regard to aerodynamic features, were identified as a factor in inhibiting adoption of fuel efficient technologies in two focus groups. As one for-hire fleet manager stated, *"I have no control. I pull other people's trailers"* (IA MG FH). While tractor owners could conceivably add their own skirts to the trailers, it would be an extremely labor intensive process to install them and remove them each time, which makes it unlikely to be time or cost effective. Vernon and Meier (2012) estimated that approximately 23 percent of heavy-duty truck trailers are subject to principal-agent problems, while Roeth et al. (2013) found mixed evidence of spilt incentives between tractors and trailers for two large fleets with very similar business models and duty cycles.

3. Liquidity Constraints

There was widespread agreement that access to financing was not a constraint to technology adoption for the companies in our sample, with good rates being offered by banks, dealers, and manufacturers. Participants in nearly every focus group and interview explicitly mentioned how easy it was: *"Right now,*

it's cheap money….They're just knocking on your door to finance you" (IA MG FH). One participant explained, "*Typically the dealer, the manufacturer will come in with some great numbers. I think it's part of the promotional package issued by the product…And they do. The last series of trucks that I purchased, it really was a coin flip between them and the bank. Bank won. But they were very, very competitive"* (MD SRH FH).

However, several participants mentioned that although liquidity constraints were not a concern in their segment of the market, they thought the high cost of new technologies and fuel price uncertainty was making it harder for owner-operators to stay in business. For example, participants noted: *"A lot of the technology is very costly, especially for smaller companies"* (MD SRH FH), and *"With the price of fuel fluctuating all the time, … it's hard on everyone but especially the little guy who depends on driving his truck every single day to make money"* (CA MG FH). Another participant stated: "*what's happened is the cost of equipment, through mandated items, non-mandated items, cost increases, raw material charges, whatever it may be, has raised the initial cost of trucks so high, that many people can't afford to replace their fleets. (INT #4 LH FH)*

Some of the companies in the focus groups, especially within the short/regional-haul groups, leased rather than purchased tractors. Only one company discussed leasing specifically in relation to fuel efficiency investments, identifying leasing as a way to guard against uncertainty in the effectiveness of new fuel-saving technologies. More often, participants mentioned leasing as a way to hedge against investment uncertainty in general to reduce reliability issues and avoid costly repairs once the tractor had considerable miles on it. No clear pattern emerged regarding the characteristics of leasees vs. purchasers in the focus groups. For example, one small company noted that breakdowns and risks of purchasing a "lemon" were easier to handle by leasing. At the same time, another noted that purchasing was preferable for small companies because it provided more flexibility to hold on to reliable trucks longer. Finally, although most discussion of leasing was not related to fuel economy decisions, it was noted in several focus groups that some new technologies would not be an option to consider if leasing because the lease provider did not generally offer it (e.g. natural gas). Adoption of other fuel efficiency enhancing technologies is automatic under a lease. For example, speed limiting technologies are generally tied into the existing electronic control system, and a company would have to sign waiver for the leasing provider to allow it to be removed.

A few firms reported having used state or federal incentives for adoption of advanced fuel efficiency enhancing technologies. However, incentives were rarely the deciding factor governing adoption. For example, some in the Maryland focus groups used dealer incentives to purchase APUs, but noted that it was something they were already comfortable using. In California, some used state financial incentives available from the California Air Resources Board (CARB) to accelerate fleet turnover. One participant also received CARB funds to purchase a few natural gas trucks but the company ended up turning it down due to infrastructure concerns. Only one of the larger companies interviewed said that it pursued grants for CNG vehicles and other fuel efficiency technologies, including low rolling resistance tires and aerodynamics (INT #2 SRH PR). Sometimes these grants tipped the scale in favor of technology adoption, but other times it was just a bonus for something they would have adopted anyway. Grants and other incentives did not seem to play much of a role in the decision making of the other interviewees, either because they found them too restrictive with hidden costs such as extra labor, or the incentives were not large enough to make it worth their while.

4. Network Externalities

Participants mentioned network externalities as a barrier to adoption of natural gas vehicles. While not a technology for improved fuel economy (i.e., diesel engines are more fuel efficient than natural gas powered engines), natural gas vehicles have the potential to lower the overall fuel cost of a trip relative to conventional diesel trucks due to the lower price of natural gas (Krupnick 2011). Thus, natural gas is an example of a win-win technology that is not yet widely adopted, which is analogous to the energy efficiency paradox.[9]

This alternative fuel technology has given rise to a classic "chicken or egg" problem emblematic of network externalities: trucking firms hesitate to invest in the vehicles due to lack of refueling infrastructure, while fuel companies are reluctant to build the infrastructure until more vehicles are in operation. Participants in every focus group and every interview noted that the lack of infrastructure for refueling and servicing of natural gas vehicles is a barrier to investment in this fuel. Only two interviewees reported adopting some natural gas trucks, and one participant in the California for-hire focus group reported trying them but would not continue to purchase them. Most other participants expressed some interest in natural gas, but lack of refueling stations, especially on the East Coast and for long-haul trips, was one of the primary reasons for delaying investment. One participant stated, *"I'm looking into natural gas right now. The problem is buying natural gas some place where I have the vehicle using it"* (INT #6 SRH PR). Another participant in Maryland explained,

> *"[In] Oregon, California, Nevada, you can buy compressed natural gas. You can buy propane very easily on the road. Here on the East Coast it's very, almost impossible to find….. It seems they did give us a website to go to, to find out where compressed natural gas was sold in the area. I think there's one station in Southern Jersey or Delaware that will sell it commercially. Otherwise you have to search around. The local bus companies are using the liquid natural gas which doesn't require the heavy tanks. But you can't get into their yards to purchase the fuel" (MD SRH FH).*

Another participant said his company planned to purchase two CNG trucks in the coming year to test them out but not for long-haul: "*With the way we run, with a local truck, I'm not concerned at all about putting CNG on it but I'm not sure if I want to go down the road yet with it*" (MD SRH PR). One participant in a California focus group reported that even generous state incentives were not enough for adoption: "*Our company actually received a million dollars worth of funding from the ARB for I think 20 natural gas LNG trucks. And we ended up declining it because the infrastructure wasn't there, and it didn't suit us at the time. Now, we're closer to it, but we're still not there*" (CA MG FH).

A few other participants noted that service network availability posed a barrier to adoption for other fuel-saving technologies as well. For example, with regard to single-wide tires, one participant stated that there is limited *"service network availability in remote areas. Problem is if you encounter a flat, many times you will also damage that rim. That's very costly to repair. So now you not only have to replace the tire but you have to replace that rim.… I can't imagine trying to get a super single in some places in West Virginia at 2:30 in the morning"* (MD SRH FH). This lack of widespread access to particular technologies or the ability to service them suggests that network externalities could play a role in curtailing adoption.

[9] Natural gas powered trucks are of interest to regulators as a way to lower CO2 emissions and the potential for meeting criteria air pollutant standards cost effectively. While reducing these types of environmental externalities is an important justification for the use of natural gas it is outside the scope of the paper.

Table 5: Barriers to investment in fuel-saving tractor technologies: other factors not accounted for by NPV calculations

Potential barriers to investment	Mentioned as barrier by participants		Sample quotations
	Focus group	Interview	
Reliability tradeoffs	6/6	4/6	*"Reliability and durability are everything. Keep the driver moving. Keep your customers happy. Keep it out of the shop. And you can offset some fuel economy from that…" –INT #3LH FH*
Fleet heterogeneity	6/6	6/6	*"I think you can take the information and you try to say, 'How does this apply to me in my particular operation?' And it's not a matter of believing what the statement is. It may be fine for this guy over here. But for me, it may not work for me."-MD SRH FH*
Risk/ uncertainty	6/6	5/6	*"… the longer the payback period, the more changes that can happen over time to make that calculation less reliable."-INT #5 SRH PR* *"When it [new technology] gets developed to where I feel that it's usable and I'm not the guinea pig." –INT #6 SRH PR*
Regulatory barriers	5/6	1/6	*"[I]t's EPA approved but it's not CARB approved …because CARB has backed themselves into a corner with their regulations that they set out to 2023 that the trucks that they force companies to get rid of, things like that, they could have run very well and very clean under dual fuel technology." –CA SRH PR*
Tradeoffs with other attributes	6/6	2/6	*"Everybody is short on drivers. And you really have to listen to your drivers. If your drivers don't like it, they'll leave. They'll go work for somebody else." -CA MG FH*

Note: each focus group is labeled according to state (CA, IA, MD); trip length (long-haul (LF), short/regional haul (SRH), or mixed group (MG)); and business type (for-hire (FH) or private (PR)). Interviews are labeled numerically in the order in which they were conducted.

B. Factors Not Always Accounted for in NPV Calculations

Focus group and interview participants highlighted a number of other barriers to adopting new fuel-saving technologies. The barriers discussed below do not fall into the category of classic market failures as typically defined by economists; rather, they are factors that make a new technology genuinely less attractive to some firms even when markets functions efficiently, despite the difficulty of including many of them in standard NPV calculations. Table 5 summarizes these barriers and provides illustrative quotations.

1. Reliability Tradeoffs

Focus group and interview participants occasionally noted that fuel-saving technologies lower maintenance costs—for instance, some noted speed limiters can reduce wear and tear on the engine. More often, though, they discussed a tradeoff between fuel efficiency and reliability and maintenance for many types of fuel-saving technologies. For example, one long-haul focus group reported that the cost of repairs made APUs "*a bigger headache than [the] fuel savings*" (IA LH FH). When a truck is only running the APU part of the time, taking the tractor out of commission for repairs exacts a high cost because it cuts into the time the truck would have been running even without the APU in use. That said, companies varied in their experiences with regard to this technology: a participant in a private focus group noted that APUs had reduced his company's maintenance costs (CA SRH PR). With regard to single wide tires, one participant in a for-hire focus group saw *"a little bit of a jump in [their] fuel mileage but it wasn't enough to justify the useful life of the tires,"* which was substantially shorter than the tires typically used. (CA MG FH) Many companies prefer the built-in duplication of double tires so that if one blows they can shut it off and keep going. This is not possible with single-wide tires. One for-hire focus group participant stated, *"I never use super singles. Never, because I'm out in the boondocks. If one of my tires goes out now, I can at least limp part of the way home. Super single, I'm dead"* (CA MG FH). In these cases, the additional expense of servicing the technology may wipe out expected fuel savings.

New technologies in particular were perceived as being less reliable. If a truck breaks down while pulling a load it is a huge expense. Participants in Roeth et al. (2013) confirmed a lack of confidence in first generation technologies due to poor performance. A company may hold onto an older tractor with lower fuel economy and less current features if it has been proven reliable. One participant described how his drivers favored a truck with over 900,000 miles on it: "*You know, that's old reliable. When we're having trouble with the new tractors, the drivers say give me [truck number] 769 and I know I'll get there"* (INT #3 LH FH). Another participant explained "*Reliability becomes much more important to the customer than did we save the last penny as far as the delivery" (INT #5 SRH PR).* A private, short/regional-haul company we interviewed preferred less complex fuel efficient technologies because they lowered the risk of breakdowns. See section B.3 for more discussion of reliability issues in the context of risk and uncertainty.

2. Fleet heterogeneity

Participants in every focus group and interview emphasized the importance of company-specific factors in evaluating whether a particular technology would work well with their fleet in reducing fuel consumption. When contemplating whether to invest in a technology *"you really have to study to see whether the truck matches your application and the type of work that you do"* (MD SRH FH). One participant described it this way: *"If we have a truck in Florida, it might be a lot different than how it's*

running in Portland" (INT #5 SRH PR). As discussed in section V.A, factors such as the length of trip, air temperature, road conditions, driver habits, the type and weight of the load, and whether the truck is driven in the city or on a highway can significantly affect the performance of fuel saving technology. *"[Average fuel economy] doesn't take into account road conditions, traffic, driver habits, inflation…. You're going to have a different result running it on an asphalt surface than you are on a concrete surface. And you're going to have a different result running it on a gravel surface than you would on a concrete or asphalt, so there's a lot of variables that need to be considered"* (INT #1 SRH FH). This means that technologies that appear to have a short payback time on average may still be a poor choice for some companies. For example, one participant said his company's trucks *"just don't run enough down the highway to be cutting the wind to pay for"* an aerodynamic feature such as a roof fairing. *"It would never ever, ever show an improvement to where it would justify the cost"* (INT #6 SRH PR).

Participants offered many other examples of circumstances under which particular technologies would not yield fuel savings (see table 6). For instance, single-wide tires reportedly have a shorter lifetime for trucks that make local deliveries because of the higher likelihood of hitting curbs and having to maneuver in tight spaces. Natural gas fueled trucks likely perform worse on hilly terrain.

Table 6: Examples of Route and Company-Specific Factors that Affect Fuel Savings of Technologies

Fuel Saving Technology	Route-Specific Factors
Aerodynamics	Best for long haul; fairings make less sense on routes that require a lot of turns or loading and unloading because likely to get ripped off or damaged; skirts only beneficial if spending a lot of time at high speed.
Single-wide tires	Shorter lifetime for trucks that make local deliveries because of likelihood of hitting curbs; because they reduce weight, may make sense for tanker trucks; do not perform well in snow.
Low rolling resistance tires	High air temperatures shorten the lifetime of these tires.
Auxiliary power units	APUs make sense for regional and long haul where drivers sleep in their cabs at night.
Natural gas fueled truck	May be more feasible for short haul fleets; since the trucks return to home each night it would be possible to refuel them from a centralized location; likely not enough power for a hilly route.
Idling reduction technology	Doesn't make sense for a tanker since it has to be turned off when loading and unloading the truck.

3. Risk and Uncertainty

In all of the focus groups, and all but one interview, participants indicated that uncertainty about realized fuel economy, reliability, and/or other hidden costs of new technologies was a reason for making conservative investments. As one participant stated it, *"We won't just jump into anything"* (MD SRH PR). The phrase most commonly used to express this reticence to adopt new technologies was that companies wanted to be on the *"leading edge,"* but not the *"bleeding edge"* (e.g., CA MG FH, INT #5 SRH PR). Since there are so many unknowns with any new technology, one interviewee said his company waits one to two years before adopting something new to "*let the bugs get worked out of it*" (INT #1 SRH FH). Another's comment was technology specific, noting he would not consider buying an electric powered truck until "*it gets developed to where I feel that it's usable and I'm not the guinea pig*" (INT #6 SRH PR). He went on to explain that the time it takes for his company to adopt something new

"*depends on how long you think that technology is going to be around before it's improved…every improvement in technology drives costs down"* (INT #6 SRH PR). Another short/regional-hauler made a similar argument for not being among the first adopters for a technology such as natural gas: the next generation of truck may end up being much better (INT #5 SRH PR). Many noted that they let the "big guys" test out new engine models for a couple of years, and participants in the Iowa long haul focus group explicitly mentioned that they purchased tractors right before new engines are released so that they can use them until the kinks have been worked out of the new ones.

Some participants opted to lease as a way to alleviate risk. For one private carrier in the Maryland focus group, leasing offered a way to try out the latest technologies. The company can always return the truck if it does not pan out. A short/regional-hauler in Maryland also mentioned leasing trucks to hedge against purchasing a "lemon." Similarly, one long haul company in the Iowa focus group noted passing some of the risk of resale off to the manufacturer or dealer by leasing; if value is not what they think it should be then they let the lease expire and return the truck; if it has been a good value then may buy out the lease and run the truck for longer.

The discussion of risk and uncertainty was often loosely tied to a company's payback requirements, noting general risk or unknowns about new technologies as a reason for wanting a shorter payback period. As one short/regional-hauler summarized succinctly, the reason is *"… the longer the payback period, the more changes that can happen over time to make that calculation less reliable"* (INT #5 SRH PR). We return to how uncertainty may affect firms' payback determinations in section V.C.

Finally, one source of uncertainty that seemed to be less of a factor in technology investment decisions for the trucking fleets that participated in our study was uncertainty about future fuel prices. Most participants expected prices would continue to rise over the long run and some had mechanisms in place to accommodate price fluctuations. For some participants, the companies passed higher costs along when fuel prices went up or for challenging routes. One participant stated, *"Our customers have accepted and adopted fuel surcharges. It doesn't matter where the price of fuel goes anymore. It's going to be covered by the surcharge"* (CA MG FH).[10] Even if prices go down, fuel is such a large expense that the most important thing is "*to get every mile out of that gallon you can*" (IA LH FH).

4. Regulatory Barriers

The role of regulation in fuel efficiency related investment decisions was discussed in all but one of the focus groups, and half of the interviews. Some regulations helped to motivate adoption of fuel efficient technologies. For example, Maryland short/regional-haul focus group participants noted that urban fees for excessive idling encouraged companies to reduce idling as much as possible with relevant technologies (MD SRH FH). Similarly, idling regulations in ports prompted APU purchases (IA MG FH). Abatement technology added to the tractor to control diesel emissions also has reportedly improved fuel economy (INT #1 SRH FH).

There was also considerable discussion of the impact of various engine emission standards, although not necessarily as a barrier to the adoption of specific fuel efficiency technologies. Many participants

[10] Fuel surcharges could create a split-incentives problem if they reduce incentives for trucking firms to invest in fuel-saving technologies. However, in the long run, firms that offer trucking services at lower cost are likely to attract customers, regardless of the contract structure. Thus, any split incentives would be unlikely to persist over time.

highlighted regulations that mandated certain changes to new truck engines that led to lower fuel efficiency and/or higher repair costs. For example, participants in multiple focus groups and interviews asserted that EPA engine standards around 2007 ended up reducing fuel efficiency through added weight and reliability problems (e.g., IA MG FH, IA LH FH, MD SRH FH, INT #3 LH FH). As one participant explained, "*It makes the truck bigger. So then you sort of chase your tail on it, and the fuel mileage isn't as good as my old Cats"* (IA MG). Others noted that technology on newer engine models (e.g., 2010) helped reverse earlier fuel economy losses (MD SRH FH). In general, we heard very little about the new Federal fuel economy regulations. In the long haul Iowa focus group, some companies are considering buying 2012 and 2013 tractors before 2014 requirements are in place so that they buy themselves a couple years to see how others fair with the new models.

Participants in the California focus groups were particularly concerned about new CARB regulations. Participants felt that some new requirements actually offset each other in terms of improving fuel economy. As one explained, *"…when I look at the CARB piece, it blows my mind because I've got to hang a side skirt, which I have no benefit of until I'm over 35 [mph], but it doesn't maximize until it's actually 65. And then I've got these low rolling resistance tires that they're requiring and they're only good up to 55 and they degradate for every mile an hour after that. So they actually offset each other. It doesn't make sense"* (CA SRH PR).

Others argued that CARB regulations rule out some promising retrofit options. For example, one participant explained that while natural gas currently wasn't a great fit for his fleet, there was a dual fuel technology that allows the tractor to run on a combination of natural gas and diesel that would be worth considering but is not permitted in California:

> *"[I]t's EPA approved but it's not CARB approved …because CARB has backed themselves into a corner with their regulations that they set out to 2023 that the trucks that they force companies to get rid of, things like that, they could have run very well and very clean under dual fuel technology. So the savings potential there for every one of his trucks is about $28,000 a year based on that truck running 80-90,000 miles a year. It could save in fuel costs alone about $28,000 a year. It's a $30,000 retrofit so it has an ROI of about 14 months on it"* (CA SRH PR).

Several participants highlighted how regulations influence fleet turnover rates. In California, the CARB regulations shorten the average life span of trucks because each year a larger percentage of the fleet has to be made up of newer model year trucks. The bigger companies seemed to have been able to anticipate these changes in their investment strategies. Some companies even found ways to keep their current upgrade cycle but move trucks around so the newest ones go where compliance is needed first. However, it was noted that many owner-operators, especially those still recovering from the recession, likely will have a much harder time meeting 2014 CARB requirements because they are not able to make investments in the newer trucks now (CA MG FH). As one participant explained,

> *"the fleets that are largely dependent on that owner-operator market are certainly going to suffer. It was supposed to be in 2013. They gave them …an extra year. But the new technology, 2007 and beyond, is so expensive. …The owner-operator used to be able to go out and spend $20,000, $25,000, $35,000 for a truck to make a decent living. He'd maintain it himself. The 2007 technologies that we just sold 20 for – we sold a group of 20 for $57,000 apiece. An owner-operator buying that is going to pay $65-67,000. They're expensive. They're not going to be able to do it….And that work force really, since these regulations started to go into full gear, is drying up. They're getting out of business" (CA MG FH).*

Long-haul trucking companies that participated in the Iowa focus group also mentioned having to meet California's regulatory requirements: "*If you go to California, you've got other pollution requirements that you've got to modernize, including the reefer units. California now requires trailer skirts, and the reefer unit has to be up to date, plus the tractor has to be up to date"* (IA LH FH).

Finally, Federal standards restricting the gross maximum weight of heavy-duty trucks to 80,000 pounds also affect adoption of fuel-saving technology by companies that gross out. Participants explained that they look for technologies that allow them to "*shed weight"* (MD SRH PV; CA MG FH) both to maximize their payloads and to reduce fuel use. That said, weight affects fuel economy even aside from weight restrictions because, according to one long haul company we interviewed, *"anytime you save weight, you save fuel"* (INT #3 LH FH). Thus, fuel saving technologies that add weight to the truck (e.g. automatic transmission, CNG, APUs, some fairings) have to pass a higher bar for adoption, while those that lighten the truck (e.g. single wide tires) lower the bar for adoption. The interaction between weight and fuel economy was discussed as an important consideration with regard to the adoption of fuel saving technologies in all six focus groups but by only one interview participant.

5. Other Tradeoffs

A variety of other factors were discussed in the interviews and focus groups with regard to potential tradeoffs or synergies with fuel economy. In particular, driver comfort and acceptance, safety, warranty, power, and customer concerns were discussed in relation to fuel economy by a subset of focus group and interview participants. (Note that tradeoffs with weight are discussed in the regulatory barriers section.) We discuss each of these factors in relation to investments in fuel economy below.

Driver Comfort/Acceptance. Participants in five focus groups and three interviews mentioned potential tradeoffs between fuel economy and driver considerations during discussions. Of those that raised potential tradeoffs with driver comfort and acceptance, only a few noted it as a potential barrier to adoption of fuel saving technologies (one focus group and one interview). Many accommodated driver comfort only if it did not interfere with fuel economy. Driver comfort and acceptance of technologies played a relatively greater role when there were concerns about driver retention. *"Some people buy these really fancy tractors because they know they'll have drivers, they're more expensive to run and everything, but if you don't have a driver, you don't even have a chance of breaking even. This is a profit making business. So you can buy the ultimate lightweight fuel-efficient tractor but you can't get a driver that likes it. It's an image thing. It's crazy"* (INT #3 LH FH). As previously mentioned, driver retention is a bigger issue for for-hire fleets, particularly long haul where the driver is on the road for longer periods of time.

While driver acceptance can be a barrier to adoption of new technology (e.g., low rolling resistance tires, idling technologies, speed limiters, automatic transmission) sometimes initial resistance can be overcome with use. For example, one participant stated *"I put a guy in one of my new [tractors], two-three weeks ago – the brand new one, automatic, and he thought, 'Oh man. I'm going to hate this truck.' Because he's an old style driver. He's used to shifting. Well, then yesterday he was in for service, he said, 'Man, I love that truck. Don't tell anybody'"* (IA MG FH).[11]

[11] A number of recent articles have touched on the acceptance of automatic transmission among truck drivers. For instance, see http://www.ccjdigital.com/are-automatic-transmissions-gaining-ground and http://www.overdriveonline.com/will-drivers-come-around-on-manual-transmissions.

Safety, Power, and Warranty Concerns. Potential tradeoffs between safety, power, or warranty and fuel economy were only discussed in a subset of focus groups and interviews.[12] For instance, safety was mentioned in both Maryland and Iowa focus groups but in only one interview (a short/regional-haul, private carrier). Some companies recognized synergies between safety and fuel economy (e.g., with speed limiters) while others noted important tradeoffs (e.g., natural gas vehicles). Tradeoffs between the warranty and fuel economy when adopting fuel saving technologies were mentioned by two focus groups and two interviews (three of which consisted of private carriers). When tradeoffs were discussed, it was only in context of potentially invalidating the warranty by adding aftermarket products to the tractor (IA LH FH, MD SRH PR); manufacturer-provided technologies were covered by the warranty (INT #2 SRH PR, INT #6 SRH PR).

The tradeoff between power and fuel economy was only discussed in one focus group (CA SRH PR) and one interview (INT #3 LH FH). Participants noted that the loss of power associated with some fuel saving technologies may have discouraged adoption (e.g., natural gas, smaller engines). One focus group participant stated that *"we're not going to put power in a truck just because the driver wants [it]...We're not going to go berserk and gobble up some more fuel."* Instead, they look for *"that sweet spot"* where they have both the power they need (for instance, to climb hills) and the fuel economy they need. (CA SRH PR) Participants in the Iowa mixed focus group discussed the loss in durability and traction associated with the adoption of low rolling resistance tires. They also noted that some fuel saving technologies that reduce power and traction may actually lower the potential resale value of a truck.

Customer Concerns. The role of the customer in tractor investment decisions was mentioned in half of the interviews and focus groups. For some it was not important at all (INT #6 SRH PR, CA SRH PR), for example, because customers don't see trucks during nighttime deliveries. For others, the trucking company invested in fairings or other types of visible technologies to satisfy customer inquiries about the greenness of the fleet (e.g., its CO_2 emissions or whether it is a SmartWay member), even when the technologies did not improve actual fuel economy (MD SRH PR, MD SRH FH, INT #3 LH FH). One participant in a private carrier focus group stated they would be at a disadvantage *"if [the customers] see all the … tractors on the road with side curtains and we're the only ones without"* (MD SRH PR). Another participant in the same focus group mentioned removing a technology when he thought the customer would not notice because it was causing damage by funneling air around the tractor while not giving any fuel economy return since is the trucks mostly sit in traffic.

C. Payback Calculations

Engineering studies and some benefit-cost analyses use payback calculations to assess whether it is profitable to adopt new fuel-saving technologies. Such calculations compare the increased upfront cost of a new fuel-saving technology (relative to a less fuel-efficiency alternative) with the value of the fuel savings to estimate the amount of time it would take for the investment to "pay for itself." We are interested in understanding whether trucking firms make similar calculations and if so, how they use the results in their investment decisions.

We found that most—five out of six—interview participants made quantitative payback calculations to evaluate new technologies. While some used formal spreadsheet programs, others took what they call a

[12] Tradeoffs such as slow refueling time and infrastructure requirements also were mentioned in quite a few focus groups and interviews in the context of adopting natural gas. See section V.D for a more detailed discussion.

"*quick and dirty*" approach that still involved quantitative calculations (INT #3 LH FH). One short/regional-haul for-hire carrier we interviewed not only analyzed new technologies in this way, but also updated the analysis once a technology had been in use for a few years and would reassess its continued use if actual performance fell short of expectations (INT #1 SRH FH). Participants from our sample generally expected a positive return-on-investment (ROI) within 18 months to three years to justify a higher-cost investment.

Many of these companies incorporated not only upfront investment cost and future fuel savings into these calculations but also considered differences in maintenance costs, resale value, labor costs, tread wear (for tires), and other factors that can be quantified in monetary terms. In some cases, these ancillary factors may yield benefits that shorten rather than lengthen the payback period; for instance GPS routing systems may curtail fuel use and also decrease the firm's paperwork burden. The desire to resell on the secondary market may also mean a company keeps a tractor for less time.

Responses among focus group participants that represented smaller companies were mixed. While at least some participants in every focus group used quantitative payback calculations, others relied instead on their own qualitative assessments or gut feelings. One participant explained, *"We know what the rate is, what this payload is... it's what you do every day. You don't need to do a flow chart"* (MD SRH FH). Those that reported a required payback period typically expected an investment to pay for itself within one to three years. One participant noted that some technologies, such as eco mud flaps, can pay back within a matter of weeks, making them "*the gift that keeps on giving*" (CA SRH PR). However, one focus group participant pointed to the business owner's desire to be on the leading edge of green technologies to justify an investment in hybrids, acknowledging that in this case, the fuel savings would not exceed the added investment cost within the tractor's lifetime.

The hybrid example, while an outlier, points to some firms' willingness to experiment with emerging technologies due to factors that are difficult to quantify. Participants highlighted other features important in tractor investment decisions that are difficult to include in a payback calculation, such as driver comfort and safety:

> *"It's not always financial. We just touched on the safety issue.... That's very important because every time an insurance company looks at you and says, 'What do you guys do?' And you can say, 'Well, we limit our speed.' It becomes the perception of you being a reliable and a responsible carrier. So is that going to net you more money in the future? It should because you should be around for a longer period of time. And your customers should appreciate what you're doing. But you really can't sit there and put a dollar value on that"* (MD SRH FH).

One commonality across most focus group participants and all interviewees was the expectation that a technology would pay for itself well before the end of its lifetime. The summary statistics in Table 1 report that no participating firms owned trucks for less than three years and most held onto their trucks for at least five years. Yet many firms required a payback period between one and three years.

Participants raised a few potential explanations for this "payback gap." One was the opportunity cost of capital faced by firms. One large private carrier noted, *"... all the different functions within a company are competing for capital, including fleet, and if we've got projects that don't compete on an ROI basis*

with those in other functions, then the capital is going to flow to the other functions that get a better payback"(INT #2 SRH PR).

Another factor contributing to the payback gap is firms' uncertainty about how technologies will perform in practice. Participants expressed concerns that, *"It's a home run then if I pay it back in two years, as long as you don't trade off any reliability or durability"* but "*a lot of things can go wrong*" (INT #3 LH FH); it may not actually achieve optimistic payback projections, particularly once maintenance and reliability costs are considered. One focus group participant commented, *"How do you know if that's going to pay two years from now? If you make that investment, they say, 'Well, in a year and a half, it'll start paying.' Well, that's assuming that nothing goes wrong"* (IA MG FH). As previously mentioned, some participants anticipated more maintenance and reliability problems from any new product relative to a trusted technology they have used for a number of years. This concern about the downside risk that a new feature will not perform as advertised illustrates the barrier that lack of information about both fuel economy and performance in general poses for technology adoption among firms in our sample.

Beyond the performance of the technology itself, some participants noted the potential for other variables in the payoff calculation to change over time, introducing additional uncertainty into the true payback time:

> *"Well, the longer the payback period, the more changes that can happen over time to make that calculation less reliable.... And after five years it gets awfully dicey. There's just so many other variables in the transportation world – the price of fuel, lubricants, tires, and drivers. The driver input is such a wide variable that you have to take into account that dynamic in that payback time"* (INT #5 SRH PR).

These views suggest that payback calculations comparing a certain upfront cost with a stream of future savings that is also assumed to be certain do not reflect the risk firms bear when adopting a new tractor feature.

D. Use of Technologies

During each interview and focus group, participants completed a questionnaire that asked about their use of 18 specific practices and/or technologies that can be added to the tractor to potentially improve fuel economy.[13] The list included fuel saving strategies related to tires, aerodynamics, powertrain, idling, alternative fuels, and driving behavior. Participants indicated whether they had tried a particular feature, and if so whether they would use it again, or whether they would consider using it in the future. Table 7 summarizes the responses received across all the focus groups and interviews. We also briefly discuss several of these technologies when they were discussed in greater detail by focus group participants. Note that there is some overlap between the technology-specific summaries and examples already discussed in earlier discussions.

Tires and Aerodynamics. We found that most participants have at least tried some features related to tires and aerodynamics. Over 80 percent of respondents have used low rolling resistance tires and over 90 percent have focused on improving aerodynamics of the tractor. The adoption of low rolling resistance tires in part seems driven by regulation and availability. They are mandated in California on

[13] A copy of the full questionnaire is provided in Appendix 4.

at least some trucks, and one participant noted, "*It's all they're making now…the only thing they're offering*" (CA MG FH). The realized payback period for these tires seems to depend on company specific factors (e.g., location, trip length). Some participants noted lost longevity and traction (especially in snow), but over 70 percent of respondents said they would continue to use them. Similarly, over 80 percent of respondents said they would continue to add aerodynamic features to their tractors.

Single wide tires, automatic tire inflation systems, and trailer aerodynamic features were less widely adopted. Many participants complained about single-wide tires, also known as super singles, for reliability reasons, servicing concerns, and required adjustments in driving behavior. As previously mentioned, these tires are problematic for companies with a large share of delivery routes in urban areas with tight curbs, and also in rural areas where service is hard to find to repair a blowout. However, the reduced weight makes them helpful to other participants because they can increase the load they carry. About half of the respondents have tried single wide tires, but only 38 percent reported that they will continue to use them; over 20 percent said they will never consider them.

Fuel efficiency benefits from automatic tire inflation seem to depend on location and the intended use of the tractor. Long haulers who are on the road a lot reported much better fuel economy when using automatic tire inflation, but others noted that the ROI is smaller than proponents claim or that it is not worth the initial cost. Instead, companies with trucks in the yard each night had the drivers check the tires after every trip and/or had a dedicated employee checking tires regularly. Similar to single wide tires, about half of the respondents have used automatic tire inflation, and about 40 percent reported that they will continue to use it.

Finally, although our study focuses on tractor purchase decisions, trailers were also discussed with respect to aerodynamic features. While most participants noted that tractor aerodynamics provide benefits, especially for long haul, they were less enthusiastic about trailer aerodynamics. Features such as side skirts (mandated in California) only yield fuel efficiency benefits at higher speeds so they are not useful for short/regional-haul operations. As previously mentioned, typically the trucking firms do not own the trailers, and putting on and removing trailer skirts for every trip is not an effective strategy from a time or cost perspective. The trailer skirts also get dirty and corroded from snow and salt. One participant stated that their drivers did not like the way they look and would rip them off (MD SRH PR). Despite these criticisms, 55 percent of participants have adopted trailer aerodynamics and plan to continue using them, and 21 percent will consider using them in the future; the remaining 24 percent had either tried them but would not use again or reported they would never even try them.

Powertrain and Idling Reduction. Nearly all participants have adopted more efficient engine technologies and 84 percent reported that they will continue to do so. As for idling reduction, the technology that received the most discussion was the APU. Views of APUs were mixed, primarily for company-specific reasons. Some companies found APUs useful for long haul, but others found them too costly because they would not use them regularly enough, or could reduce idling with driver behavior or other cheaper, proven aftermarket options. In total, 43 percent of the respondents have used APUs and plan to continue to use them, and 23 percent may consider purchasing them in the future.

Alternative Fuels. Only a few respondents reported having tried any alternative fuel powered vehicles, including natural gas and hybrids. However, natural gas came up during every focus group and interview. Some companies were in the testing phase and 73 percent of respondents said they would consider using natural gas tractors in the future. As discussed in Section V.A. above, most had not yet invested in natural gas due to the lack of fueling infrastructure. Other challenges were also

discussed. The heavy weight of the fuel tank was one deterrent. Current service facilities also would have to be redesigned for these trucks because "…*to service these trucks inside his present building, he can't do it. He would have to redesign that whole building. It would cost him a fortune to be able to do that*", or "*you have to do it outside. So it's not only the cost of the truck, there's a weight issue. But also as a service aspect of who's going to be willing to do this*" (MD SRH FH). The slower refueling time was also noted to impose an additional cost in terms of driving time and wages (CA SRH PR, CA MG FH, IA MG FH). Some had safety concerns, noting that the drivers *"weren't fans of the CNG trucks because they thought they had a big bomb behind them"* (CA MG FH).

Other Strategies. Nearly all respondents reported to have tried at least some other strategies for improving fuel economy. Most of these strategies were aimed at altering driving behavior. For example, 88 percent of respondents used speed limiters and planned to continue using them. Other driver training techniques were also widely being used, and companies found fuel saving benefits from improving their routing efficiency, with the aid of GPS and other methods.

Table 7. Participant Use of Specific Fuel Saving Strategies

	Have used and would use again	Have used but would not again	May consider in future	Never	Total responses
Tires & Aerodynamics					
Low rolling-resistance tires	72%	9%	16%	3%	32
Single wide tires	38%	13%	28%	22%	32
Automatic tire inflation system	41%	13%	41%	6%	32
Tractor aerodynamics	81%	13%	3%	3%	32
Trailer aerodynamics	55%	10%	21%	14%	29
Powertrain					
More efficient engine	84%	10%	6%	0%	31
Idling Reduction					
Auxiliary power unit	43%	17%	23%	17%	30
Auto shut-down systems (CA, IA, Int#5, 6 only)	74%	5%	11%	11%	19
Battery air conditioners (MD, Int#1-4 only)	31%	0%	38%	31%	13
Direct-fired heaters (MD, Int#1-4 only)	31%	0%	46%	23%	13
Thermal storage systems (MD, Int#1-4 only)	20%	20%	30%	30%	10
Alternative Fuels					
Alternative fuel vehicles:	0%	0%	100%	0%	8
Natural gas	9%	5%	73%	14%	22
Hybrid	6%	0%	61%	33%	18
Electric	0%	0%	63%	38%	16
Other	0%	0%	33%	67%	3
Other Strategies					
Vehicle speed limiter	88%	6%	6%	0%	33
Driver training	85%	12%	3%	0%	33
Improved routing efficiency /GPS	78%	9%	9%	3%	32
Other	60%	0%	40%	0%	5

VI. Conclusion

In this paper, we use a case study approach that relies on information gathered through focus groups and interviews to examine how heavy-duty trucking firms make capital investment decisions for fuel-saving technologies absent government regulation. A number of reports have pointed out the availability of seemingly cost-effective technologies and features that can be used to improve the fuel efficiency of a tractor, and yet they have not all been adopted by the industry. We explore several hypotheses that could explain the slow diffusion of fuel-saving technologies including market failures such as asymmetric or imperfect information, liquidity constraints, split-incentive problems, and network externalities; and factors not accounted for in typical NPV calculations such as reliability tradeoffs, fleet heterogeneity, regulatory barriers, and risk and uncertainty.

Findings with regard to classic market failures are mixed. Evidence suggests that the companies we talked with are sophisticated consumers of information on available fuel-saving technologies but that due to a high level of heterogeneity among fleets with regard to what they haul and road and weather conditions, companies conduct significant amounts of time researching and testing out whether a particular technology will result in fuel savings for their fleets. Transaction costs associated with the need for collecting company-specific information slow the adoption of new technology. However, because information about new technologies for tractors generates limited beneficial spillovers, it is unclear how much policy intervention could improve on the market in this case.

While we are not able to explore the potential for split incentives between tractors and trailers, we do not find much evidence of a split incentive problem between the original and secondary market for tractors. Many of the trucking companies that participated in the focus groups and interviews sell tractors to companies put them to very different uses than for what they were originally intended so there is good reason why fuel saving features are not valued on the secondary market. Some participants noted that they select features because of their resale value but that they are rarely related to fuel economy, while others noted that some secondary market buyers - those putting the truck to similar use or owner-operators - put a premium on fuel saving technology. Companies are well aware of drivers' effect on fuel efficiency and frequently try to address this disconnect by investing in training and technologies that limit the ability of drivers to undercut fuel savings or providing incentives for improved driver fuel economy. We also do not find evidence of a lack of coordination within the firm between those that buy fuel and those that purchase the trucks.

There is almost no evidence of liquidity constraints among the focus group and interview participants. Finally, we find that lack of infrastructure or network externalities have inhibited the adoption of some particular technologies such as single wide tires and natural gas.

Focus group and interview discussions point to a number of factors not typically accounted for in a NPV calculation as potentially important reasons for non-adoption. Companies assess tradeoffs and synergies between fuel efficiency and other attributes that are highly valued such as reliability, weight, safety, driver acceptance, and customer concerns. However, most of these tradeoffs were discussed by only a subset of participants. Driver acceptance was rarely viewed as a barrier to adoption. Some participants acknowledged that the loss of power associated with some fuel saving technologies may discourage adoption, but this concern was not widely raised. Customer perception was not an important factor in the adoption decision for companies that deliver when customers are not present, but in other cases resulted in the adoption of technology even when it was unclear that it would deliver fuel savings. Fleet heterogeneity is another important reason why some technologies that may save fuel under average

conditions may not be adopted. Companies gave many examples of technologies that failed to save fuel unless particular conditions (e.g. higher speeds, highway driving, flat terrain) were met. A faster payback is also reported as a way to guard against future risk and uncertainty – for example, that a technology will not last as long as promised or that something new comes along that will make a technology out-of-date. Companies also gave several examples of the ways in which regulations may inhibit the adoption of certain technologies, while encouraging others.

References

Allcott H (2011a) Consumers' perceptions and misperceptions of energy costs. American Economic Review, Papers and Proceedings 101: 98–104.

Allcott H (2011b) Social norms and energy conservation. Journal of Public Economics 95: 1082–1095.

American Transportation Research Institute (2007). Fuel Saving/Emissions Reducing Technologies and Incentives: Use and Preferences among Diesel Truck Owners in the Baltimore Region: Final Report. Prepared for the Baltimore Metropolitan Council. August.

American Trucking Association (2011). *American Trucking Trends*. Economics and Statistics Group.

Anderson, ST and RG Newell (2004). Information programs for technology adoption: The case of energy-efficiency audits. Resource and Energy Economics 26: 27-50.

Barr, S., G. Shaw, and A. Gilg (2011). The policy and practice of 'sustainable lifestyles.' *Journal of Environmental Planning and Management* 54 (10): 1331–1350

Carbon War Room (2012). *Road Transport: Unlocking Fuel-Saving Technologies in Trucking and Fleets*. Research Report. November.

de Almeida ELF (1998) Energy effciency and the limits of market forces: The example of the electric motor market in France. Energy Policy. Vol. 26, No. 8, pp. 643-653.

DeCanio S and Watkins W (1998) Investment in Energy Efficiency: Do the Characteristics of Firms Matter? Review of Economics and Statistics. 80: 95–107.

Energy Information Administration (2012) Annual Energy Review 2011. Table 5.24 Retail Motor Gasoline and On-Highway Diesel Fuel Prices, Selected Years, 1949-2011. http://www.eia.gov/totalenergy/data/annual/pdf/sec5_59.pdf Accessed Oct. 15, 2013.

Federal Reserve Bank of Atlanta (2012). Truckonomics: An Industry on the Move. *EconSouth*. Second Quarter.

Frechtling, J., and L. Sharp, eds. (1997). *User-Friendly Handbook for Mixed Method Evaluations*. Produced for the National Science Foundation.

Gillingham K, Newell R, and Palmer K (2009) Energy efficiency economics and policy. Annual Review of Resource Economics 1: 597–620.

Greene D (2011) Uncertainty, loss aversion, and markets for energy efficiency. Energy Economics 33: 608–616.

Gul , M., and G. Menzies (2012). Designing domestic buildings for future summers: Attitudes and opinions of building professionals. *Energy Policy* 45: 752–761.

Harris J, Anderson J, and Shafron W (2000) Investment in Energy Efficiency: A survey of Australian Firms. Energy Policy 28: 867-876.

Hassett KA and Metcalf GE (1993) Energy conservation investment: Do consumers discount the future correctly? Energy Policy 21: 710–716.

Hausman J (1979) Individual discount rates and the purchase and utilization of energy-using durables. Bell Journal of Economics 10: 33–54.

Hausman J and Joskow P (1982) Evaluating the Costs and Benefits of Appliance Efficiency Standards. American Economic Review 72(2): 220-25.

Helfand G and Wolverton A (2011) Evaluating the consumer response to fuel economy: A review of the literature. International Review of Environmental and Resource Economics 5: 103–146.

Howarth R, Haddad B and Paton B (2000) The economics of energy efficiency: insights from voluntary participation programs," Energy Policy 28(6-7): 477-486.

Huntington H (2011) The policy implications of energy-efficiency cost curves. The Energy Journal 32: 7–22.

International Council for Clean Transportation (2009). Heavy-duty Vehicle Market Analysis: Vehicle Characteristics and Fuel Use, Manufacturer Market Shares. PowerPoint presentation. May 1.

Jaffe, A. & Stavins, R., (1994). The energy paradox and the diffusion of conservation technology. Resource and Energy Economics 16(2): 91-122.

Jaffe, A. & Stavins, R., 1994. The energy-efficiency gap: What does it mean? Energy Policy 22(10): 804-810.

Jaffe, A. & Newell, R. & Stavins, R., 2005. A tale of two market failures: Technology and environmental policy. Ecological Economics 54(2-3): 164-174.

Klemick H and Wolverton A (2013) Energy-Efficiency Gap. In: Shogren, J.F., (ed.) Encyclopedia of Energy, Natural Resource, and Environmental Economics, volume 1, pp. 74-81 Amsterdam: Elsevier.

Koomey J and Sandstad A (1994) Technical evidence for assessing the performance of markets affecting energy efficiency. Energy Policy 22(10): 826–832.

Kounetas K and Tsekouras K (2008) The energy efficiency paradox revisited through a partial observability approach. Energy Economics 30: 2517–2536.

Krupnick A (2011) Will Natural Gas Vehicles Be in Our Future? Resources for the Future Issue Brief 11-06. http://www.rff.org/rff/documents/rff-ib-11-06.pdf Accessed Nov. 25, 2013.

Larrick R and Soll J (2008) The MPG illusion. Science 320: 1593–1594.

Levinson A and Niemann S (2004) Energy use by apartment tenants when landlords pay for utilities. Resource and Energy Economics 26: 51–75.

Metcalf G and Hassett K (1999) Measuring the energy savings from home improvement investments: Evidence from monthly billing data. The Review of Economics and Statistics 81: 516–528.

Murtagh, N., M. Nati, W. Headley, B. Gatersleben, A. Gluhak, M. Alilmran, and D. Uzzell (2013). Individual energy use and feedback in an office setting: A field trial. *Energy Policy*. In press.

National Research Council (2010). *Technologies and Approaches to reducing the Fuel Consumption of Medium- and heavy-Duty Vehicles*. Transportation Research Board. National Academies Press.

Broyodo Vestel, L.. Do New Bulbs Save Energy if They Don't Work? New York Times (2009) March 27, 2009. http://www.nytimes.com/2009/03/28/business/energy-environment/28bulbs.html?pagewanted=all&_r=1& Accessed Oct. 15, 2013.

Northeast States Center for a Clean Air Future (NESCCAF), ICCT (International Council for Clean Transportation), and Southwest Research Institute (2009). *Reducing Heavy-duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions*. October.

Oakridge National Laboratory (2012). Heavy Trucks. 2012 Vehicle Technologies Market Report.
Paetz, A., E. Dütschke, and W. Fichtner (2012). Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions. *Journal of Consumer Policy* 35:23–41.

Pellegrini-Masini , G. and C. Leishman (2011). The role of corporate reputation and employees' values in the uptake of energy efficiency in office buildings. *Energy Policy* 39: 5409-5419.

Peterman, A., A. Kourula, and R. Levitt (2013). A roadmap for navigating voluntary and mandated programs for building energy efficiency. *Energy Policy* 43: 415-426.

Radcliff and Best (2005). Eds. *Polling America: An Encyclopedia of Public Opinion Research*. Westport, CT: Greenwood Press.

Reeve, I., J. Scott, D. Hine, and N. Bhullar (2013). ''This is not a burning issue for me'': How citizens justify their use of wood heaters in a city with a severe air pollution problem. *Energy Policy* 57: 204-211.

Roeth, M., D. Kircher, J. Smith, and R. Swim (2013). *Barriers to the Increased Adoption of Fuel Efficient Technologies in the North American on-Road Freight Sector*. Report for the International Council for Clean Transportation (ICCT). July.

Ryghaug M and Sorensen K (2009) How energy efficiency fails in the building industry. Energy Policy 37: 984–991.

Shackley, S., C. McLachaln, and C. Gough (2004). The public perception of carbon dioxide capture and storage in the UK: results from focus groups and a survey. *Climate Policy* 4(4): 377-398.

Schleich J and Gruber E (2008) Beyond case studies: Barriers to energy efficiency in commerce and the service sector. Energy Economics 30: 449–464.

Shogren J and Taylor L (2008) On Behavioral-Environmental Economics. Review of Environmental Economics and Policy 2(1): 26-44.

Sweeney, J., J. Kresling, D. Webb, G. Soutar, and T. Mazzarol (2013). Energy saving behaviours: Development of a practice-based model. *Energy Policy* 61:371-381.

Sunstein C and Thaler R (2008) Nudge: Improving Decisions about Health, Wealth, and Happiness. New Haven: Yale University Press.

Sutherland R (1991) Market barriers to energy efficiency investments. Energy Journal 12:15–34

Thollander P and Ottoson M (2005) An energy efficient Swedish pulp and paper industry – exploring barriers to and driving forces for cost-effective energy efficiency investments. Energy Efficiency 1: 21-34.

U.S. Environmental Protection Agency (2013). SmartWay Program. EPA Technical Bulletins: A Glance at Clean Freight Strategies for Carriers. Office of Transportation and Air Quality. http://www.epa.gov/smartway/publications/index.htm#technologies. Accessed October 17, 2013.

U.S. Environmental Protection Agency (2011). Regulatory Impact Analysis for Medium-Heavy-duty Truck Carbon Dioxide Emission Standards for 2012-2016 Model Years.

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

Appendix 1 –Relevant Quotations

Upgrade Cycle

"We used to trade in every 500,000 and just do a rotation. But we've got some trucks that we've held onto over time – just value wise, we didn't run a lot of miles at the time. And now we can't trade it in because you don't know what you're going to end up with. You trade it in at 500,000 miles, you may end up with a truck that gets worse fuel mileage with the same driver. So it kind of defeats the purpose then. You spend more money to get less – basically less return on investment, so to speak (IA MG FH).

EPA regs have added more cost for no benefit or for very little benefit, I mean as far as the truck goes. Who knows when you sniff the air that comes out of a stack if it's any better or not? But we have – we are migrating now from old equipment to leased equipment – seven year lease, turn the thing back in. Because on the mechanic side, the maintenance side for a small company, that's a real issue too. If you ask somebody that's a light duty mechanic, they're not going to turn them loose on trying to fix something that is a moving target as far as what engine makers and trucks and that come up with, so we've gone to leasing – a full maintenance lease, including tires, to get away from that (IA MG FH).

We used to try to do it more on a set cycle, however now I would say it's a combination of age of the equipment and the miles that it's on. And, like he said, you look at the piece of equipment and go, "Are you having a lot of issues with it?" Then that maybe moves it up into the cycle versus maybe it really wasn't that old or maybe it didn't have the number of miles you were trying to hit, but you've had a lot of repair issues, so then it's going to get replaced (IA LH FH).

We're just trying to use the equipment to the best of our ability for the longest time we can before we have to replace them (IA LH FH).

Our fleet tends to be older. A new truck wouldn't survive out in the oil fields… Generally speaking, our runs are 500 miles per day. Once in a while, we do something longer at the rate of 1200 miles. And once in a great while, it's more like 3500 miles. But we've got the newer trucks to satisfy that requirement… It's not unusual for us to put two million miles on a motor. We have our own shop. We do our own in-frames. So we never felt the need to replace the truck (CA MG FH).

[Every] seven years, we'll evaluate where we're at. The most we'll go is eight [years] depending on the unit and what it does. But we buy every year and we just update. It's based on the year of the vehicle. So if I bought 50 tractors eight years ago, then I'm probably buying 50 tractors now (MD SRH PR).

We lease ours and it's anywhere from three to eight on a tractor… depending on the mileage (MD SRH PR).

Our purchasing behavior is pretty much flat-lined, where we order – let's call it one-tenth of the fleet every year. You retire your oldest 10 and put the new ones in on the front side. So you basically manage the fleet on a level number, rather than with an ebb and flow of good years and bad years. (INT #1 SRH FH)

We purchase… usually on a four-year cycle. (INT #4 LH FH)

We purchase, and we just purchase continually, as needed. (INT #6 SRH PR)

Importance of Fuel Economy

We look at it as part of the cost of ownership. So when you put everything in the package, that tenth of a mile per gallon difference adds up to millions of dollars over the life of the vehicle… It weighs just as heavily as everything else. So if you get a truck for free, and it has no maintenance cost ever, and it has a fuel economy that is ten times worse than the competition, you can't afford the truck, even though they gave it to you for free (INT #3 LH FH).

I'd say probably 150,000 miles a year on the trucks we turn, so fuel economy is a big – I mean when you're talking a small increase or decrease in your fuel mileage, you're talking a lot out of the bottom line and that's what makes it so high (MD SRH PR).

Our average tractor is running…28,000 miles a year. And that's very small. [For] the whole fleet, [that's] lots of fuel, but if you look at it on an each-tractor basis, the fuel isn't the biggest thing on that tractor. At 28,000 miles, if you're going to increase your fuel savings by 2 percent, which an over-the-road fleet would love to have, 2 percent at 28,000 miles, I mean that's 560 miles, that's 100 gallons of gas for the whole year. I have bigger fish to fry, I guess (INT #5 SRH PR).

O*f course, keeping something 10 years, we're looking for longevity and quality. That's why the fuel mileage [is] less important than the quality (INT #5 SRH PR).*

The price of fuel is not relevant. It's the fuel economy that's relevant (INT #1 SRH FH).

[It is] very different if you're talking about your car [saving] one tenth of a mile per gallon traveling 12,000 miles per year versus a fleet of 9,000 trucks [saving] one tenth of a mile per gallon traveling 57 million miles a month. Almost any fuel economy improvement, regardless of the price of fuel, is significant (INT #1 SRH FH).

I know what tractor I am going to buy regardless of what [fuel economy] it gets…I'd say that fuel economy does not play a major role but it's looked at. We do…whatever we can to improve it (INT #6 SRH PR).

Fuel economy is my second largest expense and it's very close to being my first. It used to always be driver wage, then fuel, then tires. But with the price of fuel going up, sometimes fuel can actually overtake driver wage….Fuel economy can speak to the program that you actually put in place, let's say, on your tires. If you don't put air in your tires, your rolling resistance changes, you're going to blow tires so you're going to add expense to that piece of it, and at the same time because you actually have more rubber on the ground as you're rolling, you have a bigger drag, therefore your fuel economy is hampered. That's something we control, we can go talk to our guys and say, 'Go put air in the tires.' …If you're talking about running millions of miles a year, it adds up very, very quickly (CA SRH PR).

[Fuel is] the most expensive part of the operation of the truck. It's more expensive than the driver (IA MG FH).

Imperfect Information – Peers

We talk to our peers. Anybody that's been in the industry for an amount of time has friends and associates that we can communicate with to verify fuel mileages and those types of things, and how something's working. Of course, statistically, engines and transmissions and those types of things, we can actually look at data for fuel mileage and RPMs and those types of things and how it's going to run out. So we review all that (INT #5 SRH PR).

We would never buy anything without talking to two or three people who have been running it first. Especially something so new…. We talked to other people that were doing it and it seemed like it would work, so we tried one and it worked, so we just keep adding them (IA LH FH).

Trucking is a pretty nice tight-knit family, so you can rely on other people in the industry pretty well (IA LH FH).

We're involved in different associations that share information, listen to other executives that have had success using one item over another. Just word of mouth, basically. Trucking is a pretty nice tight-knit family, so you can rely on other people in the industry pretty well (IA LH FH).

...you're always watching what your peers and things are doing, and the ones that you respect, the ones that you trust and respect, you'll take advice from things that are working from them and stuff. So it's not necessarily your own in-house test, but yes, you're always testing what works and what doesn't work to some degree (CA SRH PR).

I pick up the phone and call somebody that's been running one, just to validate it. Volvo can tell me they're getting the fuel mileage, but when I hear it from [my peers] Brenda and Randy, then I'm going to believe it (IA LH FH).

I think you deal with more people that you're friendly with, that you know. Even some competitors. It's not one of those things that you're going to lose business for your company or anything if you say, "Oh, yes. We got these new trucks that aren't doing so well (CA MG FH).

We do not rely on the [manufacturer's] estimates. [We] get a general idea of the specification that we're proposing to purchase but we don't count on it because we know that how we run the equipment has a much bigger impact. But you have to start with a basis, you have to feel that there's some solid ground that you're looking at as a starting point. And we try to verify with references. Who's running like equipment? Do you mind if I talk to them? A couple of quick phone calls and how they run it, and we can get an idea of how accurate those manufacturer fuel mileage statements are…We'll try a few trucks with the change, and if it doesn't pan out, they're out the door (INT #5 SRH PR).

On the low rolling resistance tires you're going to get… anywhere from 6500 to 8000 miles per 32nd, and they've got other tires out there – everyone likes to say the industry standard is 10,000 miles per 32nd. According to whom? …Who actually did the work and who tested it and where did that go (CA SRH PR)?

I'm going to want to hear from companies that have done their homework, and I'm going to want it documented that so-and-so has realized these benefits (CA SRH PR).

Imperfect Information – In-House Testing

I will verify a modification to the spec the best I can through quantitative/qualitative analysis and research, and then feel enough confidence where I might buy five of them with that change…But we're a very decentralized fleet so it's hard to bring that forward (INT #5 SRH PR).

I look at trial and error. Everybody claims they have the best thing out there. If you talk to five different people, you're going to get probably four different answers. That's why I like to try – we like to grab one and try it and see how we like it, see how it performs for us (MD SRH PR).

For the average guy, it is not real easy to do [testing] because the environments change, the temperatures change, drivers change. Unless you're on a test track in a controlled environment, there's still a lot of guess work to when we're doing our testing. And when you're trying to show tenths of a mile improvement, the ambient temperature can have an effect on that and how fast the wind's blowing. Those aren't things that a driver will pick up on. When we talk about testing, it's more you put one driver in a truck, and you assume he's going to drive it the same way. You put him on the same routes, but he can't control traffic conditions (CA MG FH).

We'll see how hard [a technology is] being pushed by the OEM, by the manufacturer. We'll look at it from their testing, when they usually do testing through their engineering and their testing facilities. Then, if it looks like it's a logical choice, a good choice for our company or a good fit for our company, we'll test a few to start with to make sure there's a good fit and that it does what it's saying it's going to do and it produces the efficiencies that it said it's going to produce. And then we'll start working our way into it. We never just all of a sudden just say, "Oh, yes, let's put those on 7,500 trucks (INT #4 LH FH).

It's challenging for fleets to figure out what gets the best fuel mileage, particularly if you're dealing with small samples, because you've got driver influence, the duty cycle influence – this tractor kind of does this because this driver does this. Unless you've got 20 or 30 or 40 in two groups and you run them in the same business cycle, then you can figure out – oh yes, these get a 10th or two better. And that allows all these companies to kind of co-mingle and nobody knows who's got the best fuel economy. Although sooner or later it kind of tells (INT #3 LH FH).

…and we've had the electronic log now for two years. You get some very interesting data indirectly from the engine in regards to fuel economy and driving habits through the system (IA LH FH).

With the data that's available, we're working on all kinds of downloading of the data, it's almost constant downloading of everything from safety information, hard braking, over-speeding, roll stability incidents, and we're going to get the fuel usage off of the ECM. And that creates a program for just putting all this in place to evaluate - is this driver driving with an egg under his foot or is he a lead foot? It's that simple (INT #3 LH FH).

What we do is we measure idle time, over speed, top gear percent, cruise control, and hard brake. And they have to meet a threshold in all five of those categories, and if they do that, the theory is that regardless of what they're hauling, regardless of the wind out there today, that truck is going to get the best fuel mileage it can get (IA LH FH).

What I do is I have my – and I'm sure we all do – we have a driver that we know is going to tell us everything we need to know about that truck. This is your truck for the next two weeks (MD SRH PR).

We also have a couple of runs that are static, they're the same miles, and it's always the same A to B, single pick, single drive so it gives us a real level playing field to compare fuel economy and anything else, performance, to know that it is really apples to apples (MD SRH PR).

We trust our own testing more than anyone else's (CA MG FH).

We will look at the estimated [fuel mileage]…But until we actually get the equipment in and … do our own testing and see what the economies are and how efficient it is in our operation, we don't say, "Go 100% on it." We'll bring some in. We'll do some of our own testing and see if it warrants any more units, or if it holds close to the claims or above the claims that they are making (INT #4 LH FH).

Imperfect Information – Data Tracking

That's what I love about PeopleNet. I get an engine diagnostic report that gives me a graph of fuel economy, vital signs, and then also what they call high resolutions (IA LH FH).

I keep 100 percent track of everything that's going on. We write it down. It goes into a computer system. We keep track of every – I pull up exactly what each truck is running per mile, all the parts go through it. I know what it's running for fuel – every single detail, so that when we try something, we get very, very serious about it (IA MG FH).

We started putting electronic onboard recorders on the trucks and I get a report that I can pull when I want to pull it. But I have it sent to me every week. And it shows the fuel economy on these particular trucks. And I look at each one of them and I know what truck these drivers are driving. It's by driver. And I can see how, number one, how the driver is doing. But I also can see how the truck is doing. One manufacturer and one engine versus another. So it's made it more visual to me (MD SRH FH).

We've got to know exactly what that piece of equipment is costing us from the day it enters the fleet, for repairs, for fuel, for down time. We measure that (IA LH FH).

Imperfect Information – Other

So I don't always believe the manufacturer or the dealers. I believe the ones that have experience – from the bigger fleets, and the Transport Topics, or some of the other magazines too. But those are the ones that I trust (IA MG FH).

The fuel economy is reported by the OEM because it's typically based on UCM algorithms, which are nothing more than a mathematical calculation. It is not real-world, and we find very consistently that what the OEM's report versus what we see in the real world is very different. So we discount that pretty heavily (INT #1 SRH FH).

Well, you've got to understand what the data is based on, what kind of testing and conditions, because that's a huge problem in the industry right now is just having a good, reliable source of test data that you can extrapolate to your own operations (INT #2 SRH PR).

...it isn't like buying a car where you walk up to the window and it says, you know, your city mileage is X and your highway mileage is X. It isn't that. The only thing the manufacturers have ever said to me as

technologies come along, "You should experience a lot better fuel economy. That's what we think." And that's all dependent upon driver, road condition, what kind of load you're pulling. There's so many variables (MD SRH FH).

You can't just go to a trade show and walk up to a booth and this manufacturer tells you this does this, and you're like, 'Sweet.' Then you buy it and find out it doesn't match real world applications (CA SRH PR).

But if it's a calculated, it doesn't take into account road conditions, traffic, driver habits, inflation. There are all those pieces that contribute to the actual benefit of that tire. You're going to have a different result running it on an asphalt surface than you are on a concrete surface. And you're going to have a different result running it on a gravel surface than you would on a concrete or asphalt, so there's a lot of variables that need to be considered (INT #1 SRH FH).

Everybody at the end of the day goes back to, 'What is it doing in my fleet?' (INT #1 SRH FH).

When we decide we're going to change a tire, I will not change any tire in my fleet until it's done a full life cycle. And at the end of the day, that's a minimum of three years. So you could have the greatest technology today and it won't be on my fleet for three years, because I'm going to validate what's that savings, what's the cost (CA SRH PR).

I think you can take the information and you try to say, 'How does this apply to me in my particular operation?' And it's not a matter of believing what the statement is. It may be fine for this guy over here. But for me, it may not work for me (MD SRH FH).

If you're the decision maker and you've done most of your homework, we've got a pretty good idea. All of us get caught once in a while but for the most part, by the time we make a decision, I think all of us have done our homework enough, we feel confident in what we do. We won't just jump into anything (MD SRH PR).

The drivers will tell you when they want to, when it's to their advantage, but a lot of times they won't until it's too late (MD SRH PR).

Most of [aftermarket] is snake oil. We've had people calling us about that, too. "Let me show you. I can do it." We tend not to even try those. Been bitten once before (CA MG FH).

There's a lot of snake oil (INT #4 LH FH).

A lot of [manufacturers] offer alternatives. You can get two different kinds of axles, two different kinds of brakes, two different kinds of electronic stability systems. You've heard about them being custom made. They're not like a car where there's very little options. So you go through that process. You asked how this works. You kind of get an idea from having tractors what's changed, what's improved, what you're having challenges with, and just trying to keep building a more reliable, fuel efficient tractor (MD SRH PR).

I don't want to say anything's better because the way the salespeople sell them to you, they're the greatest thing out there. It almost never meets – no offense – but it's rare. That's kind of a bonus if it meets with what your rep is telling you (MD SRH PR).

The drivers are the best ones because they're in it every day. The drivers will tell you. You don't need to solicit (MD SRH PR).

Drivers give you feedback whether you request it or not….You walk through the yard, you'll get it (CA MG FH).

We have trouble because of our niche market. The sales folks want to come out and talk X fuel mileage or Y life of something. And until we've actually seen it run in our niche market or our segment of the industry, I'm obviously very, very skeptical. Because, again, a truck pulling a van or a reefer [refrigerated truck] can maybe achieve 7.4 or 7.5 or 7.6, but pulling the freight that we pull, we're just not going to get that (IA LH FH).

You've got to remember all of these tests that are done are under perfect controlled conditions. That's not where we drive. We drive different roads. The urban assault on our vehicles, depending on where you go, really will dictate what you buy and don't buy. So you've got to understand it (CA SRH PR).

Split Incentives – Resale Market

We don't resell. We use [the trucks] until they're done. I guess we sell them at that time, but usually to a wholesaler or the scrap yard (INT #6 SRH PR).

One of the specifications that's used for fuel efficient tractors is really high numerical axle gearing…The engine runs a little slow going down the highway, but it has no reduction off the road and no power. If you want to get out of the mud or out of the sand, you don't have enough reduction because it takes a lot of power, even in low gear (INT #3 LH FH).

It's not that prevalent in the aftermarket that folks will pay a premium for fuel efficient technology. In fact, in some cases it's a detriment, especially in the case of say expecting a 6 by 2 instead of a 6 by 4 [axle configuration] where you actually have a dead axle instead of two drive axles in the back (INT #2 SRH PR).

You have to find the right buyer and then also overcome some of the misperceptions on some of the technology, too, because the fact of the matter is the guys that are buying used trucks are a lot less sophisticated than the ones buying new ones, and so there's a big knowledge gap there on what works and what doesn't and perceptions of some of the technology (INT #2 SRH PR).

Common wisdom would say that that tractor should command a premium with a buyer that's interested in fuel economy, but the aftermarket just hasn't proven that yet (INT #2 SRH PR).

But resale is such a tricky market too.... Everybody is looking for fuel mileage. They don't want the big, long nose [trucks]. It's no longer like it used to be (IA MG FH).

A lot of people on the secondary market use [the tractors] for construction or farming and they want the traction, so [FE technology] could hurt...So, you know, there's a little tradeoff (INT #3 LH FH).

Up until about three years ago, we were running to the ground. Just getting our million-and-two miles out of them and then just going out and getting usually a used, like two-year-old, three-year-old truck and running it to the ground. (CA MG FH).

Everybody is trying to be efficient in their operations, be low cost in their operations. Competitiveness is a key. So the secondary market is very much looking at a truck that is more efficient and more competitive and lower cost of ownership for them (INT #4 LH FH).

The secondary market might not be ready for something you put on that truck, such as automated transmissions…, such as wide-based tires. They're a deduction… in the used market. So, not everything is totally accepted in the secondary market. It would depend upon who that secondary buyer is. You might have something that works very, very well for you, but that other guy doesn't want to buy it. So now you're going to take a deduct on it because you deployed some of this technology on there (INT #4 LH FH).

Mostly everything we sell is pretty well used up, so the secondary market that we're in is more [agriculture], construction, that type of stuff that would use older trucks that are really concerned with the cost of purchasing the truck. If you're a farmer, you're not buying a new truck, you just have to get the grain out of the field to the silo (INT #5 SRH PR).

Split Incentives – Driver

Technologies are great in some ways, but training the driver is more important than a lot of these things. If they don't know how to drive, you're losing money (CA MG FH).

Absolutely, training the driver is the best way to save fuel.(CA MG FH).

The driver can make 35 percent difference from high to low – and to put that in perspective let's say you have a fleet of trucks that averages 6 miles to the gallon based on your recordkeeping; 35% either way is 5 ½ to 6 ½ (INT #3 LH FH).

The engine controls itself, but the driver controls about 40% of the – 40%-45% of the overall fuel economy of the vehicle (INT #1 SRH FH).

I think we'll all agree here that 90 percent of fuel efficiency is related to driver behavior (IA LH FH).

I mean things need to be – for them to be successful in a large fleet they need to work automatically with no intervention from the operator typically (INT #2 SRH PR).

So we just purchased six automatic transmissions. The drivers that had the high RPM, high revs, put them in automatics and the fuel economy went up (IA LH FH).

We'll incent [the drivers]a penny a mile if they can save over 10 percent [fuel economy]... And, believe me, it's worth a lot more than that (IA LH FH).

We have the mile per gallon club, the ones who get the higher miles, the ones that know how to shift better, they'll get gift certificates, rewards (MD SRH PR).

Now it's being able to control or teach the driver to have the best possible habits… There are systems out there that actually train a driver. I've looked at them briefly. I haven't gone down that road yet, but there's [a way to] train drivers to do the best job they can and pay them accordingly (IA LH FH).

One thing also we do is like we buy tractors, we'll buy extra parts. Like we do driver of the year and we'll give him options to put on his tractor if he's the driver of the year, like chrome wheels or aluminum wheels but we buy it all through the factory or distributor because of warranty. If you put an aftermarket rim on that tractor and it goes down, it's going to be a problem (MD SRH PR).

There are things you can put on trucks... that require a lot of change from the driver's standpoint or for the operation, and that may or may not be worth it in the grand scheme of things compared to an option that is transparent to the operation and does not require the operator of the vehicle to do anything drastically different (INT #2 SRH PR).

We do spec the equipment with – most recently we're spec'ing them with the automatic transmissions as opposed to the manual because the automatic transmission will shift it when you want it to every time as opposed to the driver who may be taking it up an extra 300 RPM and making that shift when you don't want him to (CA SRH PR).

Split Incentives - Other

I have no control. I pull other people's trailers (IA MG FH).

Financial Constraints

A lot of technology is very costly, especially for the smaller companies. The government made those decisions on those engines for us. We didn't have a decision to make (MD SRH FH)

Right now it's cheap money.... They're just knocking on your door to finance you (IA MG FH).

Money's real cheap right now (IA LH FH).

We've got to look at whether we're going to pay cash or get it financed, but we want to keep our money liquid so we can put in the new stores. So we're always looking at that and which way makes the best sense for the time that we're purchasing it (MD SRH PR).

Typically the dealer, the manufacturer will come in with some great [financing] numbers. I think it's part of the promotional package issued by the product….The last series of trucks that I purchased, it really was a coin flip between them and the bank. Bank won. But they were very, very competitive (MD SRH FH).

With the price of fuel fluctuating all the time, … it's hard on everyone but especially the little guy who depends on driving his truck every single day to make money (CA MG FH).

It is no longer the price of fuel that is troublesome to the truck operator. It is the cost of the equipment. We used to go by the price of fuel. If the price of fuel went up, it was, "Oh, my gosh," and trucking companies started failing or they started sucking back in again. Right now the cost of fuel, although we watch it, we are more concerned with the overall cost of the vehicle and the efficiencies of the vehicle.

The cost of fuel is somewhat negated there. If you're efficient and you're getting the best efficiency you can out of it, that's all you can do. But what's happened is the cost of equipment, through mandated items, non-mandated items, cost increases, raw material charges, whatever it may be, has raised the initial cost of trucks so high, that many people can't afford to replace their fleets. They're trying to deal with trucks on secondary equipment, secondary market. But the cost of new equipment is just being overburdened, so that most people can't afford to buy new (INT #4 LH FH).

Network Externalities

The biggest issue with [natural gas] still is they don't have the infrastructure. You can't go out to a fuel station that sells diesel and say, 'Fill me up with LNG.' It's just not there (CA MG FH).

Oregon, California, Nevada, you can buy compressed natural gas. You can buy propane very easily on the road. Here on the East Coast it's very, almost impossible to find….. It seems they did give us a website to go to, to find out where compressed natural gas was sold in the area. I think there's one station in Southern Jersey or Delaware that will sell it commercially. Otherwise you have to search around. The local bus companies are using the liquid natural gas which doesn't require the heavy tanks. But you can't get into their yards to purchase the fuel from them (MD SRH FH).

With the way we run, with a local truck, I'm not concerned at all about putting CNG on it but I'm not sure if I want to go down the road yet with it (MD SRH PR).

Our company actually received a million dollars worth of funding from the ARB for I think 20 natural gas LNG trucks. And we ended up declining it because the infrastructure wasn't there, and it didn't suit us at the time. Now, we're closer to it, but we're still not there (CA MG FH).

It's just we don't have an infrastructure to support [natural gas]. Very, very limited fuel capabilities (INT #4 LH FH).

If it were strictly fuel economy, I might go with natural gas. But the ability to get the natural gas, you know, on the operations side of the business affects that decision. Nothing is done in a vacuum (INT #5 SRH PR).

I'm looking into natural gas right now. The problem is buying the natural gas around some place where I have a vehicle using it (INT #6 SRH PR).

The issue we've seen is the service network availability in remote areas. Problem is if you encounter a flat, many times you will also damage that rim. That's very costly to repair. So now you not only have to replace the tire but you have to replace that rim.… I can't imagine trying to get a super single in some places in West Virginia at 2:30 in the morning (MD SRH FH).

Reliability Tradeoffs

Our drivers for the most part…get paid by the load. So if they're not moving, they're not making any money.… Reliability and durability are everything. Keep the driver moving. Keep your customers happy. Keep it out of the shop. And you can offset some fuel economy from that… (INT #3 LH FH).

It's all around reliability. If you're going to try a different seat for driver satisfaction, you might talk to people who have had them or tried some, but the truck's not going to break down because of the seat or the driver's not going to drive it. The rejection rate or the problem potential is low compared to an engine that won't stay running (INT #3 LH FH).

[APUs] *just ends up being a bigger headache than [the] fuel savings* (IA LH FH).

A little bit of a jump in [their] fuel mileage but it wasn't enough to justify the useful life of the [single wide] tires (CA MG FH).

I never use super singles. Never, because I'm out in the boondocks. If one of my tires goes out now, I can at least limp part of the way home. Super single, I'm dead (CA MG FH).

You know, that's old reliable. When we're having trouble with the new tractors, the drivers say give me [truck number] 769 and I know I'll get there (INT #3 LH FH).

Reliability becomes much more important to the customer than did we save the last penny as far as the delivery. Now, don't get me wrong, that's all important, but reliability and keeping the customer happy becomes much more important than saving 10 cents on fuel (INT #5 SRH PR).

When I talk about fuel savings I look at transmissions and engine combinations and gear ratios. There's very little else on the day cab tractors that I can do with fuel economy. Other things are just more important; reliability always [out]weighs it. It's just [one piece of information] that's averaged [in with] other considerations. Fuel economy is not the main focus (INT #5 SRH FH).

They don't work for us…Single wide tires in a wholesale/retail delivery application just don't improve – there's not enough incremental improvement to overcome the reliability issues. If you have a single tire, I mean you're down on the side of the road if it goes flat. And there's some fuel savings associated with that, but it's very small. So the reliability of the conventional dual tire application overcomes – is more important than the fuel savings that the single wide tires would give us (INT #5 SRH FH).

There are high traction tires that have lower rolling resistance … Somebody rolling down the interstate really doesn't care, they just want a tire that lasts, and when it does get slippery, it's okay. But we're driving 75 miles each way to our delivery and rain or sun, mud or dry pavement, and they've got to get there and get back (INT #5 SRH FH).

Low rolling resistance tires clearly do not last as long as some of the other pieces out there. So again, it comes down to life cycle. What is the cost of the tire? And at the end of the day, you've got to understand the maintenance guy would build a Sherman tank, you know, he doesn't ever want it to fail, so he would put everything on it. By the time it actually gets on the road you can't put any freight in the back of it, so you've got to find some balance in the deal (CA SRH PR).

If you stop and look at the overall picture, if we have [a single wide tire] go "bang" out there in the middle of East Baggs, Wyoming,… it'll cost you to fix [it]… I don't think you'll get your money back in fuel. I don't think you're going to get it back in longevity of the tire (IA MG FH).

Fleet Heterogeneity

I think you can take the information and you try to say, 'How does this apply to me in my particular operation?' And it's not a matter of believing what the statement is. It may be fine for this guy over here. But for me it may not work for me. But you don't ignore that. I mean, you always take a look at it and see how could it help me (MD SRH FH).

One of the things I've learned when I went to the Green Truck show is you really have to study to see whether the truck matches your application and the type of work that you do before you even think about making the investment (MD SRH FH).

Well, it's always going to take longer because we don't run the miles. The more miles you run, the quicker the payback comes. And that's the hardest thing for me to tell any vendor when they come in here. Come back in 13 years and I'll tell you how we did with it (INT #6 SRH PR).

By saying I don't want to believe in the aerodynamics of the top fairings, again it's because of the segment of the industry that I'm running in…I would say that the aerodynamics may not pay off as well for me as they would with your reefers. You've got to run the top fairings and all that stuff and the side skirts, and you'll get your money out of it, whereas the tanker runs aren't going to get a lot (IA LH FH).

It depends on how often you use it and your application. Most of our trucks aren't sitting every single night, running engine or APU for 8 hours apiece (CA MG FH).

I'm not saying they wouldn't save your company money, but mine, no. The only thing that they [fairings/skirts] do good is when you're driving interstate coast to coast where you've got long runs. When we're only running 100 miles a day, 200 maybe on some of the trailers one way, there's never going to be (unclear). That will never pay for itself in my company (INT #6 SRH PR).

Local delivery is a whole lot of difference than regional or long haul. A set of tires on one of my trucks could last eight years. So, you know, we get the payback (INT #6 SRH PR).

[With regard to APUs]…They're only running them half the time, so it makes no sense for me to take it to the shop to work on them, because now I've got three times the bill just by putting it into my own shop (IA LH FH).

We have trouble because of our niche market. The sales folks want to come out and talk X fuel mileage or Y life of something…A truck pulling a van or a reefer can maybe achieve 7.4 or 7.5 or 7.6, but pulling the freight that we pull, we're just not going to get that (IA FH LH).

I would say that aerodynamics may not pay off as well for me as they would with [someone else's] reefers. You've got to run the top fairings…and the side skirts, and you'll get your money out of it, whereas the tanker runs aren't going to get a lot (IA LH FH).

Everyone says, "Oh, you guys are doing really great on your fuel economy," because your guys are running low rolling resistance tires and everything else. But you want to know what they never thought about? The actual engine itself is most efficient at 45 miles an hour. So if I'm actually in L.A. traffic and I'm driving down the road and I don't ever get over that, and he doesn't have a single thing in front of him and he's driving 70, I'm going to be more fuel efficient than he is (CA SRH PR).

I'm not saying they wouldn't save your company money, but mine, no….When we're only running 100 miles a day, 200 maybe on some of the trailers one way, there's never going to … pay for [themselves] (INT #6 SRH PR).

Taking a trailer out on an interstate, running 10 miles down to the next exit, I'm not going to see any improvement with that on there. If I do, it's going to be so minute, it won't stand out. And if a guy over-speeds twice, he's going to use the fuel that he saved with it (INT #6 SRH PR).

Local delivery is a whole lot [different] than regional or long haul. A set of tires on one of my trucks could last eight years (INT #6 SRH PR).

The control factors vary widely. If we have a truck in Florida, it might be a lot different than how it's running in Portland (INT #5 SRH PR).

[Average fuel economy] doesn't take into account road conditions, traffic, driver habits, inflation…. You're going to have a different result running it on an asphalt surface than you are on a concrete surface. And you're going to have a different result running it on a gravel surface than you would on a concrete or asphalt, so there's a lot of variables that need to be considered (INT #1 SRH FH).

But there are [fuel-saving technologies] that we just look at and say, "No. I don't think so." There are differences in the fleets. Some guys see an advantage. We may try it and we don't see an advantage. But I'm not going to sit here and open mic, bad-mouth one over the other. I don't think that's right. It might work for somebody else. I don't know. But there are things that don't work for us and we don't deploy (INT #4 LH FH).

We don't do anything that's extraordinary with our fleet. We're a wholesale/retail distribution fleet, so we run 10 hours a day, five-and-a-half days a week. We don't double shift. We don't have over-the-road sleepers. We have tractor trailers that run short distances….We don't need to try anything wild to get the last degree of efficiency out of our equipment (INT #5 SRH PR).

Local delivery is a whole lot of difference than regional or long haul. A set of tires on one of my trucks could last eight years. So, you know, we get the payback….It's always going to take longer because we don't run the miles. The more miles you run, the quicker the payback comes. And that's the hardest thing for me to tell any vendor when they come in here. Come back in 13 years and I'll tell you how we did with it (INT #6 SRH PR).

I don't think there would ever be a point [when] I would put anything aerodynamic, other than probably a roof fairing, on my tractor. I mean we just don't run enough down the highway to be cutting the wind to [pay] for whatever I put on there…. It just would never ever, ever show an improvement to where it would justify the cost (INT #6 SRH PR).

If I was running a tanker business I would make sure that I absolutely had super single tires on my truck, because if I was actually to put the tires on there that was only one instead of two, you save 740 pounds per every axle. Now if that's the case, you can save 1,400-1,500 pounds total. It doesn't sound like a lot but when you start thinking about that, for every 30 loads or whatever that is, that's one less load I've got to drive, and considering that each of us probably know what our average miles is and what our operating costs are, you're paying $3-4 for every mile you drive down the road and your average trip is

200 plus miles, you're saving $600 just by making that move up front, putting the right piece – spec'ing the right piece of equipment to start with (CA SRH PR).

Risk and Uncertainty

You always hedge that bet. You don't know what's going to happen a year from now (MD SRH FH).

A lot of things can go wrong and you may not – and four and five years is too much money. The interest on that, the risk, you can't follow it. You need to get your payback sooner if you're really doing something on a pure ROI (INT #3 LH FH).

It depends on what that technology is, and when there is a technology specifically and unproven, we do tend to try and wait a year or two and let the bugs get worked out of it – before we implement into our fleet (INT #1 SRH FH).

What we're looking for is basically tried and true pieces of equipment, and we pretty much stay with a conservative approach. We're not leading the forefront in the industry.…We take small steps toward improvement (INT #5 SRH PR).

We're not the kind of fleet that's going to lead the way in technology. We're going to be more of a follower and let somebody else blaze the trail, and then benefit from their experience (INT #5 SRH PR).

How do you know if that's going to pay two years from now? If you make that investment, they say, 'Well, in a year and a half, it'll start paying.' Well, that's assuming that nothing goes wrong, assuming you're not ripping it [trailer skirts] off (IA MG FH).

What I've always tried to do is stay away from being the first guy on the wagon with new stuff.... Let somebody else that's got a lot of money go out there and have all the problems (IA MG FH).

Everybody has to have a fuel surcharge. If you don't, you wouldn't survive the fluctuations in diesel anymore. It's too volatile a market. You never know what's going to happen (CA MG FH).

In a line environment, that is not the case [that you make money on the fuel surcharge]. You're not paid on actual miles.…In some cases half of the fuel is burned when the truck is idling – you're not being compensated for [that]. You're not being compensated for… the empty miles that you run. So we do not make money on fuel surcharge (CA MG FH).

All of us get caught once in awhile but for the most part, by the time we make a decision, I think all of us have done our homework enough, we feel confident in what we do. We won't just jump into anything (MD SRH PR).

Especially with some of the emerging technologies, we like to say we like to be on the leading edge, but not the bleeding edge. So, hopefully, we're not buying first generation stuff. But sometimes it's attractive enough where you take a chance, whether it be with power equipment or software or whatever it is. Sometimes, you get out there and take a chance, and you end up on the bleeding edge (CA MG FH).

When it [new technology] gets developed to where I feel that it's usable and I'm not the guinea pig (INT #6 SRH PR).

[Adoption] *depends on how long you think that technology is going to be around before it's improved…every improvement in technology drives costs down* (INT #6 SRH PR).

You always assume it's [fuel price is] going to go up. It's going to go up, and at the end of the day I used to lose a lot of sleep over it, but we have mechanisms in place now to recover it. So if it starts going up, we might lag a little bit in our recovery, but it's not going to be the end of the company. And then when it falls down, we make a little money; then we lose it going back up (IA LH FH).

Being the type of personalities we are, even though you made a decision to go with that investment, the whole time you're probably saying, "This won't work. This won't work." (laughter) Then in five years you look at the financials and you go, "Damn, how about that" (IA LH FH).

… the longer the payback period, the more changes that can happen over time to make that calculation less reliable (INT #5 SRH PR).

Our customers have accepted and adopted fuel surcharges. It doesn't matter where the price of fuel goes anymore. It's going to be covered by the surcharge (CA MG FH).

The biggest thing as far as fuel is how you've got to try to get every mile out of that gallon you can (IA LH FH).

Regulatory Barriers

You talk to your dealer. If you've got a quality dealer, he's going to keep you up to date and say, "Hey, you need to buy trucks now because after the first of the year, this is going to happen," and that sort of thing (IA MG FH).

I put APUs on them because a lot of the freight we haul and load are coming out of ports. There's an ocean-going port, for instance, in Catoosa, Oklahoma, and if we go in there, we can't idle. So we'll put APUs on quite a bit of our equipment so that we can idle out here. It's a clean idle thing. And once the guys get accustomed to them, they really like them – the drivers – there's more of a demand because they can run all their microwaves, and televisions, and all that other crap they've got in there. And it's a smart idea because they really do make a tremendous difference on fuel (IA MG FH).

Well, my guys sleep and they're gone two or three weeks at a time. And I could say if we go into the ports, you're not allowed over five minutes, and they'll fine you, it's like a $500 minimum fine – or to Los Angeles, you just don't idle out there. So we don't have any choice (IA MG FH).

It'll be like the '07 engine that everybody kind of pre-bought before those new requirements came in. So you'll buy more '12's and '13's before you have to comply with the 2014 rule. So then those tractors will get you through a little bit of everybody else testing the market (IA LH FH).

We started realizing the newer the truck you bought, the more problems you had. So … you started hanging onto your older trucks longer because you don't want to get into all these new problems ...Supposedly things have turned around. But now do you want to go out and spend $145,000 for a brand new truck just to find out that it was wrong? And we have. We went out and bought a brand new one … but it's gotten more expensive to run, you know, and you're running [diesel exhaust fluid] now instead of

your older trucks that don't….Where your older trucks didn't have that, but yet they could still get similar fuel mileage for the same thing. So in that case, I guess EPA standards have really killed the trucking industry or the trucking purchases (IA MG FH).

With the 2010 emission standards because the 2007 really didn't do anything for fuel economy. In fact, it reduced the economy. But with 2010 the technology with the diesel exhaust fluid and whatever else they put into the emission standards, that did improve fuel economy and expense by what kind of operation you had (MD SRH FH).

But the lifespan of the vehicle, because of the CARB regulations, is going to be shorter than a brand-new vehicle, a 2010 or newer engine.…The thing that we're all dealing with right now is it's a law that they look at by model year of the truck or by fleet percentage, basically…. So for all of us with more than three trucks in our fleet, you have to have 30% of your fleet in model year 2007 or newer truck by the beginning of this year. And by the beginning of next year, it has to be 60% of your fleet. And then next year, it'll be 90%. And then it skips a year, for some reason, and goes to 100% (CA MG FH).

It makes the truck bigger. So then you sort of chase your tail on it, and the fuel mileage isn't as good as my old Cats (IA MG FH).

…when I look at the CARB piece, it blows my mind because I've got to hang a side skirt, which I have no benefit of until I'm over 35 [mph], but it doesn't maximize until it's actually 65. And then I've got these low rolling resistance tires that they're requiring and they're only good up to 55 and they degradate for every mile an hour after that. So they actually offset each other. It doesn't make sense (CA SRH PR).

[I]t's EPA approved but it's not CARB approved …because CARB has backed themselves into a corner with their regulations that they set out to 2023 that the trucks that they force companies to get rid of, things like that, they could have run very well and very clean under dual fuel technology. So the savings potential there for every one of his trucks is about $28,000 a year based on that truck running 80-90,000 miles a year. It could save in fuel costs alone about $28,000 a year. It's a $30,000 retrofit so it has an ROI of about 14 months on it (CA SRH PR).

The fleets that are largely dependent on that owner-operator market are certainly going to suffer. It was supposed to be in 2013. They gave them …an extra year. But the new technology, 2007 and beyond, is so expensive. …The owner-operator used to be able to go out and spend $20,000, $25,000, $35,000 for a truck to make a decent living. He'd maintain it himself. The 2007 technologies that we just sold 20 for – we sold a group of 20 for $57,000 apiece. An owner-operator buying that is going to pay $65,000-$67,000. They're expensive. They're not going to be able to do it….And that work force really, since these regulations started to go into full gear, is drying up. They're getting out of business (CA MG FH).

It's important when you're … developing your specs to know exactly what's coming down the pipeline in order for you to remain in compliance (CA SRH PR).

If you go to California, you've got other pollution requirements that you've got to modernize, including the reefer units. California now requires trailer skirts, and the reefer unit has to be up to date, plus the tractor has to be up to date (IA LH FH).

Tradeoffs with driver comfort/acceptance

Everybody is short on drivers. And you really have to listen to your drivers. If your drivers don't like it, they'll leave. They'll go work for somebody else (CA SRH FH).

If you tell the driver you're going to put him in an electric truck and haul 80,000 pounds...he's going to say, 'Why don't you just fire me?' (MD SRH FH).

As I mentioned, some people buy these really fancy tractors because they know they'll have drivers, and they're more expensive to run and everything, but if you don't have a driver, you don't even have a chance of breaking even. This is a profit making business. So you can buy the ultimate lightweight fuel-efficient tractor but you can't get a driver that likes it. It's an image thing. It's crazy (INT #3 LH FH).

I put a guy in one of my new [tractors], two-three weeks ago – the brand new one, automatic, and he thought, 'Oh man. I'm going to hate this truck.' Because he's an old style driver. He's used to shifting. Well, then yesterday he was in for service, he said, 'Man, I love that truck. Don't tell anybody' (IA MG FH).

We're not going to put power in a truck just because the driver wants [it]...We're not going to go berserk and gobble up some more fuel (CA SRH PR).

Talking about bringing the drivers into this, we do try and take the drivers' input on this because, you know, it is their office for 10-12 hours a day, and one of the biggest resentments you'll get from the people that have to use this equipment is when they think that we sit around a table like this and make decisions for them, and never sit in the truck and never listen to them (CA SRH PR).

Other tradeoffs or synergies

Any time you save weight, you save fuel (INT #3 LH FH).

There's so many factors. Just take fuel tanks, for example. You can be concerned over a weight issue and what's the use of that truck. Does that truck need 260 gallons of capacity or is it fine with smaller tanks, lighter weight which allows you to haul more because it goes short distances (CA SRH PR)?

So fuel-wise you do things like that, and then you start looking at the tires themselves. How much does it weigh? Not only what does it weigh, but how am I going to run it (CA SRH PR)?

When you fill out forms [for new rate proposals], they'll want to know, "Are you SmartWay certified?" … I think that sometimes they don't know much about it but they just want to be on the [band]wagon with it (MD SRH FH).

We put [side curtains] on all our tractors; they didn't mean anything to us. We just don't get that benefit but we have them on the tractors because it's the image thing (MD SRH PR).

[We would be at a disadvantage] if [the customers] see all the … tractors on the road with side curtains and we're the only ones without (MD SRH PR).

We wouldn't buy an add-on that would invalidate the warranty (IA LH FH).

All of our deliveries are nighttime unattended, about 90% of them are, so customers don't even see the trucks. They'll know if we didn't show up because the loads aren't sitting there (CA SRH PR).

We want to spec it right to get that sweet spot where we have the power we need to climb the Grapevine and then the fuel economy we need (CA SRH PR).

Take natural gas, for example. If we want to go to a Class A truck, which is what I think we're all operating, natural gas isn't necessarily a real good fit because … you're talking about a spark fire engine as opposed to a compression engine, and so you generally have a tradeoff there in your power (CA SRH PR).

Payback Calculations

It's what you do every day…We know what the rate is, what the payload is. You don't need a flow chart (MD SRH FH).

It's not always financial. We just touched on the safety issue. That's very important because of CSA 2010. That's very important because every time an insurance company looks at you and says, "What do you guys do?" And you can say, "Well, we limit our speed." It becomes the perception of you being a reliable and a responsible carrier. So is that going to net you more money in the future? It should because you should be around for a longer period of time. And your customers should appreciate what you're doing. But you really can't sit there and put a dollar value on that. You really can't (MD SRH FH).

It's a home run then if I pay it back in two years, as long as you don't trade off any reliability or durability (INT #3 LH FH).

We expect about a three year cash payback on any kind of fuel saving technology, so if it can't with a reasonable degree of risk or certainty, if it can't meet that payback term, then there's other stuff that we could be working on that does (INT #2 SRH PR).

It may not be a formal spreadsheet, but I've sat down and done a quick and dirty on Excel and said, "Okay, if you pay this much more for it and you get 1/10 a mile per gallon, then how much fuel have you saved?" Yes, the fuel efficient tire is one of the best investments you can make (INT #3 LH FH).

I think most businesses say anything that's two years or less, you've got to do it (INT #3 LH FH).

I wouldn't really look at return on investment because it makes me money every day, but as far as – like when I do a major project, if I can get it under three years, we go with it on lighting, retrofit or whatever, but on a tractor, no. I mean it's a necessary evil. I mean I hope we would pick one that'll last seven years without a lot of maintenance (MD SRH PR).

I know there are certain things that that purchase is going to cost me a little extra, so if my payback is at one year, two years, and I figure I've got three to four years that I can actually save some money, or theoretically save money. Because if it doesn't pay off prior to the end of the depreciation period, then why would I spend the money (IA LH FH)?

How do you know if that's going to pay two years from now? If you make that investment, they say, 'Well, in a year and a half, it'll start paying.' Well, that's assuming that nothing goes wrong (IA MG FH).

Well, the longer the payback period, the more changes that can happen over time to make that calculation less reliable.... And after five years it gets awfully dicey. There's just so many other variables in the transportation world – the price of fuel, lubricants, tires, and drivers. The driver input is such a wide variable that you have to take into account that dynamic in that payback time (INT #5 SRH PR).

I can tell you right now our V.P.'s won't sign up for spending more money unless they're going to get it back within a year, a year to 18 months. [If] it's under a certain dollar amount, you just go do it. And if the ROI is really quick, and even though it's going to cost a little bit of money, if you're a risk taker and you believe what you know is right, you just go do it and you ask for forgiveness at the end of the day. And truly, the idea that by the end of the year you will have actually given back more than what it costs and no one will say anything.... e.g., eco mud flap has 18 week payback so within one quarter of reporting, it's already done. So you just build that into your parts line. If they say, 'Why are you spending so much more money in parts?' You say, 'Look at how much I saved in fuel.' Oh, and by the way, that's going to be the gift that keeps giving as we work through this and it's a one-time cost (CA SRH PR).

And so all the different functions within a company are competing for capital, including fleet, and if we've got projects that don't compete on an ROI basis with those in other functions, then the capital is going to flow to the other functions that get a better payback (INT #2 SRH PR).

I get all these reports. I probably only look at half of them. I've got my favorite ones that I like. A lot of times I think it goes back to the old sanity check, when those reports are generated you've got to have a gut feel for what the answer should be before the reports are generated. And my CFO is great. He'll build these spreadsheets off these cool reports, but at the end of the day you've got to gut check it somehow. You've got to know right here what the answer is going to be before you validate it (IA LH FH).

I don't [calculate payback], just for the simple reason we don't earn revenue with them [the tractors]. They're needed to deliver a product that our factories manufacture, and we buy them and we use them until they're worn out. So looking at return on investment, we'll get it. I don't have it penciled out exactly where we get it. I could probably tell you, but there's been no need ever in my life to calculate that (INT #6 SRH PR).

For me, I manage it very simply. If it looks right, feels right, tastes right, smells right, it's probably right. And if it doesn't match those and it has anything to it, I'm gone (CA SRH PR).

It's always going to take longer because we don't run the miles. The more miles you run, the quicker the payback comes. And that's the hardest thing for me to tell any vendor when they come in here. Come back in 13 years and I'll tell you how we did with it (INT #6 SRH PR).

If we were Schneider, a private for-hire fleet, I could tell you exactly every frickin' penny that goes into every vehicle and whether or not it's worth buying. When you're a private fleet, the same questions don't work, especially when you're running local (INT #6 SRH PR).

The tractor is the must-have. We're out of business if we don't have it and so it's more of a fixed expense (MD SRH PR).

If we can get it to pay for itself in three years, it would be a good investment. Or if we could get some help on back side – and maybe that'll come about in the future….If you can get a couple thousand dollars on the back side, then that helps the ROI (CA MG FH).

I would say that's everybody's goal, to be able to run it past the time of payments, but before the repairs cost you (IA LH FH).

It has to pay back before, otherwise why would I invest? (IA LH FH)

The longer the payback period, the more changes that can happen over time to make that calculation less reliable. So if, as an example, I'm going to keep a truck 10 years and I calculate the payback is I'm good at eight, I'll have two years to benefit, so I should make that change. And maybe I would if … it's going to be [a] seven, eight or nine [year pay back] and there's very little risk of anything [changing], … but there's a lot of changes to the industry and something might come along inside of that eight years that would even be better. When you get out there in payback calculations beyond five years, [it's] a crap shoot. You're either going to get your investment back or you're not. And after five years it gets awfully dicey. There [are] just so many other variables in the transportation world – the price of fuel, lubricants, tires, and drivers….If it's not inside of five years, I have a hard time wrapping my arms around it and saying that's a value (INT #5 SRH PR).

Some things are a no-brainer, that certainly goes into the calculations, but that may not be true for everybody here. I know at least one of us here or probably two of us are using reefers, which is another thing (CA SRH PR).

Natural Gas

[In] Oregon, California, Nevada, you can buy compressed natural gas. You can buy propane very easily on the road. Here on the East Coast it's very, almost impossible to find (MD SRH FH).

It seems they did give us a website to go to, to find out where compressed natural gas was sold in the area. I think there's one station in Southern Jersey or Delaware that will sell it commercially. Otherwise you have to search around. The local bus companies are using the liquid natural gas which doesn't require the heavy tanks. But you can't get into their yards to purchase the fuel from them (MD SRH FH).

The challenge with natural gas is the infrastructure. If you were willing to do the straight trucks and they were going to be home in your yard every night, no brainer. But for over-the-road, I just – I think we're a long ways from that (IA LH FH).

They had the natural gas thing out at BP here a few months ago. It wouldn't work in my operation at all because you can't go – my average trip is about 600 miles. You couldn't even make a full trip without stopping and refueling, I think. And the refueling of natural gas – even in the fast (unclear), it's about 20 minutes. Then the other, if it's slow fill…. It's just not feasible for me (IA MG FH).

The cost savings are…half the price of diesel fuel. You have to look at it. As the infrastructure comes on, of course, it'll be a much easier decision for us. It does kind of fit us because we return to base every night, so we don't have the problems of finding fuel on the road. If they come back in and have got natural gas, they'd be good to go.(INT #5 SRH PR).

I guess the CNG thing is pretty big in certain states. We don't have any yet but we're looking at that. It's all about, can you get fuel? It's the chicken and the egg, you know… We haul a lot of gasoline locally so it's a good place to run a CNG truck. There's not so much power, but you better have a CNG station that's fast fuel, otherwise – and these trucks are run 24 hours a day. Now the people who adapted it first are the people who have trucks parked all night – school buses, garbage trucks, and they have slow fill. They hook them up just like plugging them in, you know, and they go home (INT #3 LH FH).

To service these trucks inside his present building, he can't do it. He would have to redesign that whole building. It would cost him a fortune to be able to do that", or "*you have to do it outside. So it's not only the cost of the truck, there's a weight issue. But also as a service aspect of who's going to be willing to do this* (MD SRH FH).

[Drivers] weren't fans of the CNG trucks because they thought they had a big bomb behind them (CA MG FH).

Take natural gas, for example. If we want to go to a Class A truck, which is what I think we're all operating, natural gas isn't necessarily a real good fit because … you're talking about a spark fire engine as opposed to a compression engine, and so you generally have a tradeoff there in your power (CA SRH PR).

If I was to have to drive to Vegas and I didn't have the range because I was running compressed natural gas or something, so I had to fuel it up somewhere along the way, I could actually lose because now I've got to pay the driver a wage to actually pull over, fuel it up multiple times that he wouldn't have had to do before, even though I might be getting the fuel cheaper (CA SRH PR).

Tires

Because rolling resistance is less and it's just teetering on that. And my only response to them is that they drive differently, you have to drive them differently and you slow down (IA LH FH).

It's all they're making now…[low rolling resistance tires are] the only thing they're offering [in California] (CA MG FH).

They don't work for us…Single wide tires in a wholesale/retail delivery application just don't improve – there's not enough incremental improvement to overcome the reliability issues. If you have a single tire, I mean you're down on the side of the road if it goes flat. And there's some fuel savings associated with that, but it's very small. So the reliability of the conventional dual tire application overcomes – is more important than the fuel savings that the single wide tires would give us (INT #5 SRH PR).

A little bit of a jump in [their] fuel mileage but it wasn't enough to justify the useful life of the [single wide] tires (CA MG FH).

I never use super singles. Never, because I'm out in the boondocks. If one of my tires goes out now, I can at least limp part of the way home. Super single, I'm dead (CA MG FH).

There are high traction tires that have lower rolling resistance … Somebody rolling down the interstate really doesn't care, they just want a tire that lasts, and when it does get slippery, it's okay. But we're

driving 75 miles each way to our delivery and rain or sun, mud or dry pavement, and they've got to get there and get back (INT #5 SRH PR).

I don't know if you're familiar with how tires work, but when you've got a wide tire like that with a fully loaded trailer and you've got to drive through six inches of snow, that's a lot of snow to move from side to side. When you're running a two tire application, half of that snow will build up between the two tires and make getting through the snow a lot easier (INT #6 SRH PR).

APUs

We tried APU's and we didn't feel that we were getting a return on them. We thought we could manage it better by just managing our idle and our driver behavior (IA LH FH).

[APUs] *just ends up being a bigger headache than [the] fuel savings* (IA LH FH).

It's the cost, weight, and then the dependability. They're only running them half the time, so it makes no sense for me to take it to the shop to work on them, because now I've got three times the bill just by putting it into my own shop. You just cannot save enough fuel to recoup the initial investment plus repairs and the fuel (faint voice). The numbers don't work, at least not in our fleet they don't work, so we're not buying more (IA LH FH).

Appendix 2 – Screener (Baltimore Example)

Name: _____

Company: _____

Address: _____

City/State/Zip: _____

Phone: _____

Date/Time of Interview: _____

Recruiter: _____

General Information/Recruiting Specifications

- Recruit 10 participants for each group for a show of 5-6.
- Group 1: National or long-haul for-hire carriers, April 11, 2012 10am-noon
- Group 2: Smaller regional or short-haul local for-hire carriers, April 11, 2012 1:30-3:30pm

ASK TO SPEAK TO the Vice President of Operations or Fleet Management, someone at the company that makes the purchasing decisions for the company's truck fleet?

(Introduction to respondent): Hi, I'm _____, with ICF International, a national research and consulting firm. We are conducting focus groups and interviews for a research study on how trucking businesses make investment decisions related to new technologies. We're looking for people like you who are involved in the day-to-day management of a truck fleet and help to make purchase and lease decisions. Your participation will help us to learn about fleet managers' experiences, needs, and concerns with the use of new technologies. We highly value the expertise and knowledge that fleet owners and managers, like you, have learned through operating a business. And, if you choose to participate in the focus group, you'll have a chance to talk with some other people like you about your common experiences.

I would like to ask you a few questions to see if you qualify. This is NOT a sales call. The information is for research purposes only and ICF will keep your identities confidential.

(If the respondent asks, the research is being done by the National Center for Environmental Economics at the United States Environmental Protection Agency.)

Provide OMB Number if requested - *This project has been approved by the U.S. Office of Management and Budget (OMB). The OMB Clearance Number is 2090-0028.*

(ASK IF THEY ARE AVAILABLE FOR A FEW MINUTES NOW OR IF RESCHEDULING THE CALL IS NECESSARY. *GET FIRST <u>AND</u> LAST NAME <u>AND</u> DIRECT TELEPHONE NUMBER OF REPSONDENT.*)

1. Do you do either of the following in your position? (Read a-b)

	Yes	No
a. Participate in decisions about purchasing/leasing combination tractors	☐	☐
b. Participate in decisions about purchasing/leasing after-market products for combination tractors	☐	☐

(If all responses to a-b are "no," ask if there is someone else at the company you could talk with that fulfills this role. *Otherwise, terminate* now with "Thank you very much for your time. It appears that you don't qualify for our study".)

2. Are the majority of the trips taken by your tractor fleet within 250 miles of your base of operations?
   a. Yes (regional, short haul carrier)
   b. No (national, long haul carrier)

3. Do you specialize as a/in **(circle all that apply)**
   a. Truckload carrier
   b. Less than truckload carrier
   c. Tankers
   d. Refrigerated loads
   e. Expedited
   f. Drayage …….. **Terminate now with "Thank you very much for your time. It appears that you don't qualify for our study."**
   g. Other, specify _____

4. What proportion of your overall fleet do combination tractors represent?

   Enter amount here: _____

5. Does your fleet also include tractors owned or leased by independent contractors?
   a. Yes
   b. No

6. How long do you typically hold onto a tractor before you replace it? **(circle one)**

    a. Less than 3 years
    b. 3-5 years
    c. 5-7 years
    d. 7-10 years

    More than 10 years

7. Is your company a partner in the EPA SmartWay Transport Partnership?
    ☐ Yes
    ☐ No

(We want to ensure that there are both Smartway Partners and non-Partners in each focus group, ideally, a 50/50 split is desired.)

8. What is the size of the combination tractor fleet? Include only those vehicles directly owned or leased by the company.

    Enter amount here:_____

If fleet size equals 1 - 4 tractors → Terminate now with "Thank you very much for your time. It appears that you don't qualify for our study."

WRAP UP TEXT FOR THOSE THAT QUALIFY FOR A FOCUS GROUP OR INTERVIEW:

A. IF THE RESPONDENT HAS A <u>FLEET SIZE OF 5-150</u>, PLEASE INVITE THEM TO PARTICIPATE IN A FOCUS GROUP (Group 1 = National, Long Haul; Group 2 = Regional, Short Haul):

<u>If quota for a particular type of firm is full (e.g. SmartWay; Short Haul group is full but still recruiting for Long Haul), use wrap-up text B below.</u>

"I'd like to invite you to participate in a focus group **(if they ask, a focus group is a small group discussion)** with other people like yourself to help us better understand how businesses like yours think about investments in new technologies. The discussion will last about 2 hours. Refreshments and snacks will be provided. The discussion will be held on April 11th **[insert time 10am or 1:30 pm]** at Observation Baltimore, in Catonsville, Maryland right off of I-95 and I-195. We will send the details. "

Will you be able to attend?

☐ Yes

☐ No

If NO: I'm sorry you're not able to participate in the Focus Group. However, given that you fit the characteristics of a participant, we would like to offer you the opportunity to participate as an interview candidate. Would you mind if we contacted you at some point in the near future to set-up a 1-hour interview to elicit information about how you manage your company's trucking fleet and make investment decisions? Thank you for your time.

If yes: I'm glad that you will be able to join us! At this point, I need to make sure I have your correct contact information: **enter contact information on last page.** I'm going to [mail/e-mail] you a confirmation letter and directions to the facility.

If for some reason you're unable to come, please call or email me *[insert contact and phone, email]* as soon as possible.

We look forward to having you participate on *[insert appropriate date and time]*. The session will begin promptly at **____ am/pm** so please be there at least 15 minutes early to get something to eat and sign a consent form. If you are not there on time, you won't be invited to join the group late. We look forward to your participation.

B. IF THE RESPONDENT HAS A <u>FLEET SIZE OF 5-150</u> BUT QUOTA IS FULL (E.G. SMARTWAY; SHORT HAUL IS FULL BUT STILL RECRUITING FOR LONG HAUL GROUP):

"Thank you very much for your time. Based on your responses, it appears you don't qualify for our group discussion because our quota for businesses of your type is full. However, it is possible that we may hold another focus group in which you could participate. This would consist of a small group discussion

with other people like yourself to help us better understand how businesses like yours think about investments in new technologies. The discussion would last about 2 hours. Would you be interested in participating in such a group discussion? **If yes, enter contact information on last page and indicate possible focus group participant.**

C. IF THE RESPONDENT HAS A <u>FLEET 150-500</u> TRACTORS:

"Thank you very much for your time. Based on your responses, it appears you don't qualify for our group discussion because our quota for businesses of your type is full. However, it is possible that we may hold another focus group in which you could participate. This would consist of a small group discussion with other people like yourself to help us better understand how businesses like yours think about investments in new technologies. The discussion would last about 2 hours. Would you be interested in participating in such a group discussion? **If yes, enter contact information on the last page and indicate possible focus group participant.**

We also may conduct some one-on-one interviews, most likely over the phone. Would you be interested in participating in an interview? **If yes, enter their contact information on the last page and indicate possible interview.**

D. IF THE RESPONDENT HAS <u>FLEET > 500</u> TRACTORS:

"Thank you very much for your time. Based on your responses, we feel you would be most suited to the one-on-one interview format for participating in our study. We plan to conduct these interviews within the next couple of months, most likely over the phone. We would ask you some questions that would help us better understand how businesses like yours think about investments in new technologies. The discussion would last about an hour. Would you be interested in participating in such an interview?

If yes, enter their contact information on the last page and indicate possible interview. Close by saying: We will be back in touch with you in the near future to set up a time. Thank you.

☐ Focus Group Participant ☐ POSSIBLE Focus Group Participant ☐ Interviewee

Name: _____

Address: _____

Telephone # (Day): _____(Evening) _____

E-mail Address: _____@_____

Appendix 3 - Moderators Guide

I. WELCOME AND INTRODUCTION (10 minutes)

A. Introduction of the moderator

Good morning/afternoon. My name is <insert name> and I am the moderator. I am working with ICF International, an international research and consulting firm located near Washington, DC. Our client is interested in hearing your opinions about how trucking firms make investment decisions related to the adoption of new and existing tractor technologies and what factors influence the decision process.

B. What is a moderator?

Before we begin, I want to let you know that I'm not an expert on trucking or the investment decisions you and your companies make. My job as a moderator is to:

- Help guide the flow of conversation
- Make sure everyone's comments are heard
- Ensure that the questions our client has are covered

You will see me referring to this outline during our session. The outline includes all issues I need to raise with the group, and helps me keep the discussion on track. Since we need to cover all the issues, I may have to break off the conversation to move on to another area. The questions at the end of the guide are just as important as the ones at the beginning.

C. Ground Rules

Before we begin, I'd like to review some ground rules for today's discussion.

- We are audio and videotaping our discussion today. The tapes will be transcribed and our client will use the transcription to prepare a report. Your names and the companies you represent will never appear in the transcripts or any report that is written.

- Because we are taping the discussion, I ask that you speak loudly and clearly. If I think you are speaking too softly to be heard, I will ask you to speak up.

- Please speak one at a time so everyone has a chance to participate and we can hear you easily on the tape. And please, no side conversations.

- Sometimes I'll go around the table and ask everyone for their input. At other times, I will just throw a topic open for general discussion.

- Participation -- we would like to hear from everyone in the group, but you don't have to answer every question.

- There are no right and wrong answers. We expect differences in how people see things, and we want to know about these differences. It's important to tell us YOUR thoughts, not what you think others will think, or what you think others want to hear.

- Feel free to disagree or question each other. The purpose of a group session is for us to learn things in group interchanges that we don't get out of one-on-one discussions. If someone says something you disagree with, please let us know.

- Some observers are listening in by phone. They want to hear what you have to say about the topics we'll discuss, but we don't want you to feel constrained by their presence. They have each signed an observer confidentiality form.

- If anyone needs to use the restroom, they are located (specify). There is no need to stop the discussion. Also, about half way through the conversation, we will take a few minutes to complete a questionnaire. During that time, you can also use the facilities or refill water glasses.

- If you have a cell phone, please turn it off or set to vibrate.

- The session will last about two hours.

D. Informed Consent

All participants will have reviewed and signed the informed consent for their participation in the focus group prior to coming into the focus group room. This will be handled by a designated staff at the focus group facility. ***[Moderator: make sure you have a copy of the form that you can hold up.]***

Before coming into the room, you were asked to review and sign an informed consent form. I just want to go over some of the key points on the consent form to make sure we are in agreement.

Review consent form, emphasizing audio- videotaping, confidentiality, and use of first names only.

Does anyone have any questions?

E. Introduction of Participants

Let's start with introductions. Please introduce yourself—first name only—and tell us:

- How long you've been in the industry;
- The type of company you work for (long distance hauling, independent owner-operator, regional, logistics, movers, etc.),
- What you do, what types of things you haul, and
- The approximate number of tractor-trailers owned or leased by the company

NOTE TO MODERATOR: Questions 1 and 2 are **warm-up questions** to get the discussion going but should not last more than five minutes.

The main objective is to find out how often they buy/lease a tractor for the fleet (also to use later in ROI or payback discussion) and what factors are most important to their tractor purchase decisions and **whether fuel economy appears** in this list. If they mention trailers, that's OK but we want to focus the discussion on tractors.

Probe on **why** the factors mentioned are important, but no need to understand which rank first, second, or third or get consensus on what ranks in the top three.

II. OVERVIEW OF CHOOSING AND BUYING TRACTORS (20 minutes)

1. To get us going, what are the top 3 factors you consider when you select a tractor for your company's fleet? [***Moderator: write factors on newsprint]***

   Probe: Why these particular factors?

   Probe: [**IF FUEL ECONOMY IS NOT MENTIONED**,] Where does fuel economy rank? Near the top, middle, or near the bottom?

2. Do you purchase or lease tractors on a set cycle, or on an as-needed basis?

   How often do you make new purchases/how long are your lease agreements (e.g. every five years; we roll over 10 percent of the fleet each year)?

3. Starting from the idea that you want to acquire a one or more new tractors …

    a. How do you gather information on tractors you are thinking of acquiring? ***[Moderator: if necessary mention possible sources:*** suppliers, conferences, in-house testing, truck shows, people you know, outside organizations]

        i. What is the role of the supplier as to which tractors (or the types of technologies) you consider?
        ii. What about drivers?
        iii. Customers?

NOTE TO MODERATOR: For question 4, we'd like to know how the information gathering and decision process applies to **tractors with new**, whether it differs between **new vs. used vehicles**, and **purchased vs. leased**.

Probe further if these types of issues arise: Prior focus groups indicate that they test new technologies on a few trucks first; ownership allows flexibility on when to turn over a particular truck; leasing reduces maintenance; and reliability issues with newer engines pushed some to the used market.

4. How do you decide whether to try out a new feature you haven't used before (e.g. new electronics, different fuel type, an APU)? What type of information do you need to inform this decision and where do you get it?

    a. **[Moderator:** ***if participants lease, ask the following]*** How does leasing instead of buying affect the process we've been discussing?

    b. By a show of hands, does anyone buy or sell tractors on the secondary market (i.e., used)? **[Moderator:** ***if participants buy or sell used, ask the following]*** How does this affect the process we've been discussing?

III. THE ROLE OF FUEL ECONOMY (45 minutes)

NOTE TO MODERATOR: In this section, your focus should be on how fuel economy fits into the purchase decision – specifically, we want to know if there are **barriers to adopting fuel saving technologies** and how fuel economy considerations are **weighed against other factors** (e.g. driver comfort or safety).

At the very beginning you all ranked fuel economy to be *[important, somewhat important, not that important]* when choosing and buying tractors.

5. How many of you have chosen specifications or features for a recent tractor purchase with the goal of improving fuel economy?

    a. **Why** those features? What makes them appealing to adopt?

        What factors did you consider when deciding whether to adopt them?

    b. Are there fuel economy enhancing features you have chosen not to adopt? Can you give an example?

        Why did you not buy a tractor with these features?
        What factors did you consider when deciding whether to adopt them?

6. Have any of you considered an after-market product (installed after purchase) that improves tractor fuel economy (e.g. APUs, fairings or aerodynamic mirrors)?

    a. What are the main reasons why you do/do not consider them?

NOTE TO MODERATOR: For the next question, we want to find out whether **borrowing constraints** in capital markets, **additional costs incurred** as a result of adopting a particular technology, other **non-financial factors** such as driver comfort or safety, and **other trade-offs** such as reliability or lower resale value matter when making these decisions. If they do not mention these, ask them.

I have a list of factors here that you might consider when purchasing a tractor – some you have already mentioned – that I want to ask you about.

7. Does _____ factor into your purchase decision? If yes, how important is it? How might it come into play?

    Ask about any factors not already discussed:

    - Borrowing constraints/access to financing,

- Additional costs (e.g., added weight, required infrastructure)
- Reliability or maintenance concerns,
- Warranties,
- Driver retention/acceptance or safety,
- Expected use of tractor (e.g. routes, distance)
- ***[If applicable]*** Resale price of a tractor; Will a buyer pay a premium for used trucks with better fuel economy?
- State or Federal incentives

NOTE TO MODERATOR: The purpose of question 7 is to find out if firms account for the **perceived accuracy** of fuel saving estimates (fuel savings are sometimes based on "typical" use or available estimates are considered unreliable); or **uncertainty in future fuel savings** (because it's hard to predict the future price of diesel or it's unclear whether a new technology will deliver the promised savings).

We've heard that some firms test a technology on 1-2 trucks to evaluate whether they merit adoption. We are interested in finding out if others do this as well. Also be on the look-out for hints of **split incentives** (between truck and fuel purchasers).

8. I'd now like to ask you about how you estimate and consider fuel savings in your purchase decision.

    a. How does available information about estimated fuel savings affect your tractor purchase decision?
        1. How reliable are the estimates you look at?
        2. Are there estimates that you don't believe or bother looking at? Why?

    b. How does the future price of fuel affect your tractor purchase decision?

9. Thinking about all the factors you have mentioned so far, do you incorporate any of them into an ROI or payback calculation?

    a. If so, how?
    b. If not, how do you weigh them against the upfront cost and fuel savings?

    [**PROMPT:** Example factors: unexpected change in fuel price, access to financing, maintenance, warranty, driver retention/happiness, resale value, incentives...]

IV. OPINIONS ON SPECIFIC TECHNOLOGIES AND PAYBACK (40 minutes)

Before we start the next discussion, please take five minutes to fill out a brief questionnaire.

[HAND OUT QUESTIONNAIRE: Shouldn't take longer than 5 minutes to fill out]

NOTE TO MODERATOR: Questions 10 and 11 dig into particular technologies. **Do not cover the entire list** of technologies from the questionnaire.

Depending on time and responses, we recommend following up on a few technologies in each category. We are interested in **why they did or did not adopt them**. What factors make them more or less appealing? Please drill down a bit, including technologies that have been mentioned briefly in earlier discussion.

Looking at your responses, I notice that the technologies we discussed earlier are *[a bit different from/pretty similar to]* this list, made before the meeting. I'd like to spend a little time discussing some of them to investigate why you think these technologies make sense to invest in or not.

10. I notice that some of you considered *[insert technology name]*. What were the main reasons why you considered this technology? **[REPEAT QUESTION FOR A FEW TECHNOLOGIES BUT NOT ALL]**

    a. If you ended up adopting this technology for your fleet, what were the main reasons **why**?
    b. If you ended up not adopting this technology for your fleet, what were the main reasons **why**?

11. ***(Skip if they considered all the technologies on the list)*** How about those you haven't considered. For instance, many of you indicate that you did not consider *[insert technology].* What are the main reasons you haven't considered them?

Let's return to the earlier conversation we had about ROI or payback in the context of a few of these technologies.

NOTE TO MODERATOR: In question 12 we want to know why – in spite of what looks like a very short payback (or high ROI) – they aren't adopting them.

12. Let's look at: **(Choose 1 example)**

Example 1: [low rolling resistance tires or aerodynamics]. I've looked up an approximate estimate of payback for low rolling resistance tires/ aerodynamics**.** Based on the fuel savings, the higher upfront cost is estimated to pay back in less than a year.

Example 2: [Idle reduction technology – specifically, APUs – for long haul only] I've looked up an approximate estimate of payback**.** Based on the fuel savings, the higher upfront cost is estimated to pay back in two years.

a. Do you make similar sorts of calculations when making purchasing decisions?

    i. If not, what sorts of financial assessments do you make?

    ii. How do you decide what is or is not a worthwhile investment?

b. Some companies have told us that the payback period they need to justify investing in a fuel saving technology is less than the amount of time they hold onto a tractor (1 -4 years for payback but holding onto the vehicle for 7 years).

    i. Is this true for you?

    ii. Why do you need an investment to pay back sooner?

    [**Prompt**: If they don't say much or say it's a company rule of thumb, probe further: Do you know why it's a company rule of thumb? Is it to hedge against certain uncertainties - e.g., future fuel prices, true technology effectiveness? Do you shift your trucks into a different type of service after a few years (e.g., to shorter hauls)? If so, does this factor into how you calculate ROI?]

Moderator – ask clarifying questions. If none continue to Wrap-Up

V. WRAP-UP (5 minutes)

So today we've discussed the general process for buying a tractor and how fuel economy factors into that process. Through this discussion, we've learned that … ***[Moderator: Fill in with general findings about the decision and purchasing process about fuel economy improving products.]***

13. Those are the main questions I have for today, but before we finish up, I wanted to take the time to check-in with you all and see if there's anything we haven't discussed here today that would influence what type of fuel economy technologies or other strategies you'd choose or buy for your fleet?

I want to take this time to thank you for your input and sharing your expertise. Your time and ideas are valuable to helping us understand your decision making process.

14. Does anyone have any last questions or comments?

Appendix 4 – Questionnaire

1. Are the majority of trips taken by tractors in your fleet within 250 miles of your base of operations?

   ☐ Yes ☐ No

2. What is the typical distance a tractor in your fleet hauls its freight in a single trip?
   _____

3. What is the typical distance a tractor in your fleet travels during an entire year?
   _____

3. What is the average payload weight carried by a tractor-trailer in your fleet?
   _____

4. What percent of your tractor fleet do you buy new vs. used?

Percent buy new: _____%
Percent buy used: _____%

5. What percent of your tractor fleet do you purchase vs. lease?

Percent purchase: _____%
Percent lease: _____%

6. How long do you typically own a tractor before replacing it? **(circle one)**
   a. Less than 3 years
   b. 3-5 years
   c. 5-7 years
   d. 7-10 years
   e. More than 10 years

7. For tractors you purchase used, what is the typical age of a tractor at the time of purchase (if applicable)? **(circle one)**

e. Less than 3 years
f. 3-5 years
g. 5-7 years
h. 7-10 years
i. More than 10 years

8. How does your company purchase fuel: (circle all that apply)
   a. Retail
   b. Wholesale
   c. Use of discounts through association membership or work through a larger carrier

9. Has your company considered or purchased a tractor with any of the following fuel-saving strategies: **(check all that apply)**

	Has used and would use again	Has used and would not use again	Never used, but would consider in the future	Never used, and would not consider
<u>Tires</u>				
Low rolling-resistance tires	☐	☐	☐	☐
Single wide tires	☐	☐	☐	☐
Automatic tire monitoring or inflation system	☐	☐	☐	☐
<u>Idling Reduction</u>				
Auxiliary power units (APUs)	☐	☐	☐	☐
Auto shut-down systems	☐	☐	☐	☐
Other, specify: _____	☐	☐	☐	☐
<u>Aerodynamics</u>				
Tractor aerodynamics	☐	☐	☐	☐
Trailer aerodynamics	☐	☐	☐	☐
<u>Powertrain</u>				
More efficient engine	☐	☐	☐	☐
Other, specify: _____	☐	☐	☐	☐
<u>Alternative Fuels</u>				
Natural gas powered tractors	☐	☐	☐	☐
Hybrid tractors	☐	☐	☐	☐
Electric-powered tractors	☐	☐	☐	☐
Other, specify: _____	☐	☐	☐	☐
<u>Other Strategies</u>				
Vehicle speed limiter	☐	☐	☐	☐
Driver training or incentives to improve fuel efficiency	☐	☐	☐	☐
Improved routing/GPS to reduce fuel use	☐	☐	☐	☐
Other, specify: _____	☐	☐	☐	☐