High Efficiency Trucks: New Revenues, New Jobs, and Improved Fuel Economy in the Medium and Heavy Truck Fleet

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Table of Contents

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Executive Summary

The move to high efficiency trucks can lead to new revenues and jobs for companies involved in the development and marketing of the technologies needed to make this transition. But in order for the medium and heavy truck industry to make this transition, there will be a number of barriers to overcome. This study, funded by CALSTART, examines these challenges, estimates the potential revenues and jobs that may be created, and discusses the policy options available to government.

The basis for this analysis is a survey of the manufacturers and suppliers that make up the medium/heavy truck industry. We divided potential new technologies into three groups, aerodynamics, hybrid/electric, and other powertrain technologies supplied from a previous analysis by the Union of Concerned Scientists (UCS). There are significant differences in the cost and sophistication of the technologies within as well as among these groups. Our analysis is based on the responses of 31 companies (from an original 90) that are either marketing or developing 52 of the new technologies.

Two of the three challenges to introducing these new technologies, as reported by the executives who participated in the survey, focus on building the business case for the trucking industry to introduce the new technologies and ensuring customer acceptance of the technologies. The other major challenge is the technology challenges that still exist for some of the new technologies. These are significant challenges because the medium/heavy trucking industry, which runs on narrow margins, makes technology decisions based not on emotion but on business economics.

The study was designed to estimate the current and future revenues and jobs for the three technology groups whether they were "in-market" or "in development." Analyzing the current and future revenues and jobs yielded the following insights.

Revenues:

- Executives with technologies in-market report that hybrid/electric technologies provide more revenue than the aerodynamic and other powertrain technologies
- Executives were asked to look out over the next 10 to 20 years and consider low growth and high growth scenarios for their technologies. They report that for all 52 technologies, the average revenue will be higher for their in-development technologies compared to their in-market technologies.
- In a high growth scenario, they expect nearly twice as much revenue than in the low growth scenario.

Jobs:

- Currently, most jobs are in the hybrid/electric group, and in manufacturing and R&D, except for aerodynamics executives who report many more jobs in the aftermarket and dealer sales/service.

- In general, executives report technologies that are in-development will produce more jobs than those that are currently in-market.
- Hybrid/Electric technologies are reported to provide more jobs than the other technologies, and more jobs will be created in manufacturing. Aerodynamic technologies are expected to provide many jobs in the aftermarket and dealer sales/service.
- Most jobs will be new jobs, though a significant number will be retained jobs from those that may have been lost during the recent recession.
- For this group of sampled companies, nearly 60 percent say that they will manufacture their technologies outside their companies, though smaller companies are more likely to do this than larger companies.
- Aerodynamic companies are more likely to manufacture their technology inside their company than the other technologies.

Potential Revenue and Job Growth at the National Level

Because executives reported on a variety of technologies in each technology group, our estimate for the current number of jobs related to each of the three technology groups is based on the current market share for a technology and the number of current jobs reported by executives for a technology. We used technologies that are in-market, because they have a market share to use to for weighting job reports. We also used job reports from technologies in-development, using the same market share weights as the in-market technologies. By combining the job estimates for in-market technologies and current in-development technologies we have current estimates of jobs for cross sections of the three technology groups: 3,244 for aerodynamic technologies, 5,922 for Hybrid/Electric technologies, and 1,762 for Other Powertrain technologies.

For measuring the potential job growth related to the three technology groups we used a combination of the survey results, estimates of the value of the technologies in 2020 and 2030 from the Union of Concerned Scientists, and our estimates of productivity improvements over time. UCS provided estimates for the dollars of revenue they predict will be generated for each of the technologies in two scenarios: The Reference scenario (Reference)[1], and the Policy Scenario (Policy). The Reference scenario is based on gradual growth of the new technologies, while the Policy scenario is based on government support for the growth of the technologies.

This range of estimates creates boundaries for estimating the effects of different scenarios on job growth due to the new technologies. These job estimates are incremental from today's baseline. We do not attempt to quantify jobs retained that may be lost if companies based outside the U.S. take the lead on these technologies, as has happened to a certain degree in light duty vehicles. For the individual technology groups, the range of potential jobs varies by technology. Aerodynamic jobs are predicted to grow more than the Hybrid/Electric and Other Powertrain jobs because of the potential growth related to retrofitting the current fleet of tractors and trailers

[1] The input assumptions for the Reference scenario were largely based on the high technology case used in the DOE's Annual Energy Outlook 2008 report, which uses the underlying assumptions for medium and heavy-duty fuel economy technologies from an Argonne National Labs study from 2002 (Vyas, 2002). Technology is only adopted which meets simple payback requirements as specified in the National Energy Modeling System (NEMS) model and is reflective historic adoption rates.

and also because it is a non-specialized technology that supports the development of more fuel efficient trucks. Thus, for 2020, estimates for aerodynamic technologies range from 5,274 jobs in a Reference scenario up to 11,235 jobs in the Policy scenario. For 2030, aerodynamic technologies range from 12,816 jobs in the Reference scenario up to 18,950 jobs in the Policy scenario. But aerodynamic technologies are not expected to see the same percentage improvement in jobs as the other technologies. For 2020, aerodynamic jobs are expected to increase by 143 percent while in 2030 jobs are expected to increase 69 percent.

For 2020, estimates for Hybrid/Electric technologies range from 197 jobs in a Reference scenario up to 1,511 jobs in the Policy scenario. For 2030, Hybrid/Electric technologies range from 200 jobs in the Reference scenario up to 3,375 jobs in the Policy scenario. Hybrid/Electric technologies are expected to see a higher percentage improvement in jobs than the other technologies. For 2020, Hybrid/Electric jobs are expected to increase by 443 percent while in 2030 jobs are expected jobs to increase 1074 percent.

For 2020, estimates for Other Powertrain technologies range from 221 jobs in the Reference scenario up to 491 in the Policy scenario. For 2030, Other Powertrain technologies range from 519 in the Reference scenario up to 1,395 jobs in the Policy scenario. Other Powertrain technologies are expected see more percentage improvement in jobs than aerodynamic technologies. For 2020, Other Powertrain technology jobs are expected to increase by 83 percent while in 2030 jobs are expected jobs to increase 121 percent.

It is important to note that our estimates of both current and future jobs are limited by the data and modeling inputs. Current and future job estimates are confined to three major technology areas (aerodynamics, hybrid/electric, and other powertrain) and do not take into account possible job growth in other advanced technology areas such as weight reduction and tires. Furthermore, for the current job estimates, our analysis is limited to specific technologies within the three major technology categories for which data was available. The current job estimates therefore present a representative but conservative snapshot of all jobs tied to advanced truck aerodynamics, hybrid/electric, and other powertrain improvements.

Policy Options for Supporting New Technologies

Executives report that truck purchasing incentives, manufacturer R&D incentives, and increases in fuel prices or taxes would be most effective in supporting the move to more fuel efficient trucks. They also think that a combination of these same government actions would be needed to reach a 30 percent increase in fuel efficiency: Twenty-one percent of suggestions (mentions) focused on truck purchasing incentives, 19 percent of the suggestions spoke of manufacturer R&D incentives, 17 percent of the mentions talked about fuel economy standards, and 12 percent of the mentions focused on increased fuel prices/cost. A number of the executives expressed concerns about some of the negative effects or unintended consequences that some of these regulations or incentives can create.

Introduction

The government focus on reducing U.S. dependence on foreign oil and reducing CO2 emissions has led to a major commitment by companies to provide the new technologies that will support this change in policy. The light duty vehicle market has taken the lead in developing alternative powertrain technologies while the medium and heavy duty fleet has begun to examine the advantages new technologies may have for companies and the country.

Though the recent recession has had a dramatic effect on the light, medium, and heavy duty vehicle industries, the force of change driven by the government has opened up avenues for the research and development arms of current manufacturers and suppliers to create the fuel efficient technologies of the future. But this policy change has also affected the growth of smaller companies that have been developing fuel efficient technologies for many years. The change in policy has changed the equation companies used for years to measure the value of new materials, aerodynamics, and powertrain technologies. Technologies that were once considered too expensive to put on a vehicle are now considered part of the solution to improving fuel economy. The economies of scale that come with the adoption of technologies across a vehicle fleet offer companies new technology introduction opportunities.

This report will look at some of the new technologies that will be part of the medium and heavy truck fleets (Class 4 to 8) and how the introduction of these new technologies may affect revenues and employment. A number of studies, including our own, have examined the employment effects of the introduction of new fuel efficient technologies in the light vehicle fleet[2]. But the medium and heavy truck market and industry is very different from the light vehicle market. In fact, the two markets are so different that very few comparisons can be made between them. Some of the major differences include:

- Market: Light vehicle sales, though down because of the recession, averaged about 15-16 million vehicles per year since the turn of the century. Medium and heavy truck sales averaged about 500,000 per year.
- Manufacturing: Light vehicle manufacturers make all the critical decisions about what features and powertrains they will build in their factories. Most medium and heavy trucks are customized to customer orders outside the traditional factory. Using a multi-stage assembly process across three types of companies, medium/heavy vehicle assembly is made up of Truck Cab-Chassis Manufacturers and Dealers (about 16 companies), Truck Body, Equipment and Trailer Manufacturers (about a 1000 companies), and Truck Body, Equipment and Trailer Distributors (about 2000 companies)[3].
- Products: Light vehicles have a limited amount of customization compared to medium and heavy vehicles. These customizations include safety features, cab exteriors and interiors, powertrains, braking systems, and trailer configurations.

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[2] Patrick Hammett, Michael Flynn, and Maitreya Kathleen Sims, and Daniel Luria. 2004. *Fuel-Saving Technologies and Facility Conversion:Costs, Benefits, and Incentives.* University of Michigan Transportation Research Institute, Automotive Analysis Division and the Michigan Manufacturing Technology Center. Sponsors: National Commission on Energy Policy and the Michigan Environmental Council.

[3] National Truck Equipment Association, *About the Industry*, http://www.ntea.com/content.aspx?id=2432&linkidentifier=id&itemid=2432

- Engines: Light vehicles introduced the world to hybrids and soon will introduce pure electric and fuel cell engines, while medium/heavy vehicles are experimenting with some of these technologies in their fleets.
- Duty cycles: Light vehicles have typical duty cycles of about 200,000 miles while many medium duty and all class 8 trucks have duty cycles in the hundreds of thousands if not millions of miles. The cycles include powertrain replacements and upgrades.
- Used vehicles: There are over 240 million used light vehicles in the U.S., whereas there are about 9 million used medium/heavy trucks. Light vehicles are traded amongst the population throughout a vehicle's lifecycle, whereas medium/heavy vehicles are almost always traded when they will receive the most return for the owner.
- Users/Buyers: The biggest difference that affects technology choices between light vehicles and medium/heavy vehicles are the users/buyers of the vehicles. Light vehicles are overwhelmingly individual household purchases, while medium/heavy vehicles are almost exclusively purchased for business.

The business aspect of medium/heavy vehicle purchasing determines in large part how new fuel efficient technologies will penetrate the fleet. The word "fleet" accurately describes how most of these trucks are purchased and used. Our study of advanced safety technologies of class 8 vehicles showed that the overwhelming number of companies that make up the class 8 trucking population have only one to three trucks in their fleets, and that less than 0.5 percent of all the companies own 50 percent of the trucks.[4] The class 8 population is thus made up of very small and very large fleets.

The fleet aspect of the medium/heavy truck industry is crucial to understanding how new technologies enter the industry. Each fleet, no matter how small or large, is continually weighing the cost advantages or disadvantages of anything related to its vehicles. Small fleets are able to manage everything related to their vehicles because they are so small, while large fleets use sophisticated analyses to wring the most profit out of every vehicle purchase. Because these companies tend to run on very narrow profit margins, they are always assessing the value of new technologies for their fleets. Even when government demands that changes be made to the U.S. overall fleet, managers will, at times, wait until they absolutely have to make required changes.

This situation occurred in the early 2000s when the U.S. government demanded that engines meet more stringent emissions requirements. Just before the mandate went into effect, fleet managers/owners purchased the older versions of the engines instead of the newer versions because they were less expensive and got slightly better fuel economy. These decisions set back the timing for the environmental benefits that the government was hoping to gain from the introduction of the new technology. Though all new engines meet the requirements and the environmental gains are accruing, these older engines are probably still working their way through the used vehicle system.

There are triggers or incentives government can use to derail these unintended consequences of new regulations, but these examples are instructive about how new technologies enter and

[4] Bruce Belzowski, Daniel Blower, John Woodrooffe, and Paul E. Green (2009) "Tracking the Use of Onboard Safety Technologies Across the Truck Fleet." For the Federal Motor Crash Safety Administration. Onboard Safety Technologies Report

penetrate medium/heavy truck fleets. Thus it is easier to predict how quickly new regulated technologies will penetrate the medium/heavy truck fleet once one understands the motivation of fleet owners. But in the case of a variety of potential technologies that are not required but can be used to meet a forthcoming standard, predicting the penetration rate(s) is more difficult.

Thus when this report, based on a sample of companies involved in the development and marketing of new fuel efficient technologies, estimates the revenues and jobs related to the introduction and dispersion of the technology across the medium/heavy truck fleet, we and the companies involved are basing our estimates heavily on the technology's potential value to the companies that are developing the technologies, but within the context of the companies that are purchasing the technologies.

Goals of the Study

This study aims to accomplish a number of goals:

- To understand the challenges companies face in developing and marketing these technologies.
- To estimate the current revenues three sets of technologies provide for their companies and the future revenues they will provide through an industry survey of companies involved in the development of these technologies
- To estimate, through an industry survey, the current number of jobs the three technology sets generate currently and the future jobs they will generate.
- To estimate the number of jobs that may be created in the 2020 and 2030 timeframe using the survey estimates, revenue estimates provided by the Union of Concerned Scientists, and productivity measures based on our analysis of government productivity data.
- To estimate the effectiveness of certain government policies in support of the development, sale, and use of more fuel efficient trucks.

The Study Sample

Most estimates of revenues and jobs based on new fuel efficient technologies are based on numerous assumptions of current jobs and revenues or historical analysis of similar technologies. Based on our review of the literature, no one has actually asked companies that are actively involved in the developing and marketing of these technologies what revenues they expect and how many jobs will be created.

Because of limited funds and because there is no census of all companies involved in the development of these technologies, we sampled companies from a combined list of UMTRI-AAG's Powertrain Database (about 600 companies) and CALSTART's high efficiency truck industry database (about 100 companies). We selected 90 companies to contact about participating based on our knowledge of their products within the medium/heavy truck industry. Our final number of 31 telephone interviews represents a 34 percent response rate which is very high for industry surveys, especially those that ask sensitive business questions about the future direction and revenues of a company.

Each company was asked to describe up to three technologies it was either currently marketing or developing from the technology groupings we provided. For our purposes, our unit of analysis became the technology that was reported rather than the company itself. Thus the 31 interviews yielded 52 technologies with complete data for our key revenue and jobs variables that are the focus of our analyses. (If we include interviews with partial data for the key variables, we have 63 technologies.) These technologies do not represent all of the possible technologies that may be used to increase fuel economy in the medium/heavy duty fleet, but they represent most of the main aerodynamic, hybrid/electric, and other powertrain technologies that are being considered.

The 31 companies represent a cross section of medium/heavy truck powertrain companies. Some of the companies were very large with revenues in the billions of dollars while others had revenues of only a million dollars. While the larger companies develop both the current and new technologies, the smaller companies specialize in the new technologies. Without the increased emphasis on these new technologies these smaller companies would not exist. In some cases these smaller companies have been developing these technologies over many years, waiting for the opportunity for increased investment. These differences in size of company account for some of the large discrepancies in the amount of revenues and jobs companies reported.

Describing a company as a manufacturer in this industry is complicated because there are large companies that develop engines, while other companies separately develop the chassis, body, and trailer. For our purposes, we considered all of these companies as manufacturers. Table 1 shows the distribution of manufacturers and suppliers, while Table 2 shows the distribution of the size of the participating companies. Table 3 reports the title of the people interviewed.

Considering the number of larger companies that make up the industry, this sample has more smaller companies than in some analyses. But many of the new technologies that are the focus of this study are being developed by smaller companies. In fact, some of these technologies are also being developed by smaller companies in the light vehicle market. This is a particularly fertile time for new technology companies outside the traditional automotive supply chain, especially those that focus on the electrification of vehicles. This is an area where established manufacturers and suppliers are still developing their expertise, and they are drawing on these new companies for some of that expertise.

Table 1: Types of Companies in the Sample

Type of Company	% of Companies
OEMs/Manufacturers	14%
Suppliers	86%
Total	100%

Table 2: Size of Companies in the Sample

Size of Company (Revenues: 2008)	% of Companies
<$99 million	46%
>$100 million	54%
Total	100%

Table 3: Title of Interviewees

Title	% of Interviewees
CEO / President	15%
Vice-President	39%
Director	14%
Manager	32%
Total	100%

The Technologies

For this study, we focused on three sets of technologies that represent the largest fuel efficiency technology groups available to the medium/heavy truck industry, as measured by expected future investment:

Fuel Efficient Technologies
1) Aerodynamic Technologies: aerodynamic improvements of tractors or trailers
2) Hybrid/Electric Technologies: hybridization or electrification of powertrains, accessories, auxiliary power units, starters/alternators or braking
3) Other Powertrain Technologies: other diesel or gasoline engine improvements such as turbocharging, direct injection, HCCI, gasoline direct or electronic fuel injection, dual overhead cams, multiple valves, bottom cycling, or even engine friction reduction due to improved lubricants or bearings.

These categories come from a previous analysis by the Union of Concerned Scientists who found that these categories will represent about 90 percent of the expected future investments in fuel economy technologies for medium/heavy trucks.[5]

These categories were never considered equivalent in their impact on revenues or jobs. Aerodynamic technologies, in general, are considered relatively inexpensive considering their impact on fuel economy. Within the Hybrid/Electric technology group there are significant differences in potential revenues and jobs coming from a variety of technologies. For example, hybrid-diesel powertrains will be much more expensive than auxiliary power units or starter/alternators or braking, but the revenues generated from one of these less expensive technologies may provide more revenue if they propagate through more of the fleet. The Other Powertrain technology group is similar to the Hybrid/Electric group because of the wide variety of expensive and less expensive technologies that may have different penetration in the market.

A common thread throughout this analysis is the growth expected of aerodynamic technologies. Though there are only a few aerodynamic technology responses in our study (there are only a handful of aerodynamic companies in the country), some of the larger manufacturers are also

[5] UCS Climate 2030: Blueprint for a Clean Energy Economy, Appendix E
http://www.ucsusa.org/global_warming/solutions/big_picture_solutions/appendices-climate-2030.html

developing aerodynamic technologies, and they are expecting very large growth in this technology. Aerodynamic technologies are considered the low hanging fruit for increasing fuel economy, especially in class 8 trucks. The technology itself is relatively inexpensive for the fuel consumption improvement (8-10%) compared to other technologies. It also provides opportunities for jobs outside the aerodynamic companies through aftermarket providers and dealers. Finally, the opportunity to retrofit the existing fleet with these technologies offers even greater growth potential. Few technologies can be as easily installed on all current tractors and trailers.

Though we categorized technologies reported by companies into these three groups, companies described a variety of different technologies within these categories. One of the major distinctions we made for these technologies was whether they were in the market or in-development within the company. Table 4 shows the percentage of technologies of both categories. The large number of technologies that are in-development shows the general slow introduction of these technologies into the marketplace, and it may represent some uncertainty of the executives about the future revenues and jobs related to the introduction of these technologies.

Table 4: Percentage of Technologies "In-market" and "In-development"

Technology	% of Technologies
In-market	46%
In-development	54%
Total	100%

Table 5 shows the technologies that are currently in the market and their reported market share as reported by the executives interviewed. Some technologies are duplicates of others in the table because the executive may have been discussing a technology related to a hybrid engine, for example, rather than a complete hybrid engine. Separate reporting of these technologies also shows the different market shares companies currently have or expect for their technologies. Table 5A shows the average market share for the in-market technologies that make up each of the three technology groups. This tables shows the aero technologies with a higher market share followed by Other Powertrain technologies and lastly by Hybrid/Electric technologies. This result may represent the low level of Hybrid/Electric technologies currently in the market.

Table 5: Reported Technologies Currently in the Market and Current Market Share

In-market Technology	Current Market Share
Aero: Trailer Skirt	30
Aero: Gap Reducers	75
Aero: Truck Body Aerodynamics	40
Hybrid/Electric: Diesel Hybrid Engines	40
Hybrid/Electric: Hybrid Engines	15
Hybrid/Electric: Fuel Cell Membranes	30
Hybrid/Electric: Hybrid Engines	50
Hybrid/Electric: Hybrid Powertrains	50
Hybrid/Electric: Electrification of hydraulic systems	10
Hybrid/Electric: Electronic Controllers	5
Hybrid/Electric: Electric Pumps	15
Hybrid/Electric: Plug in Hybrid Drivetrains	1
Hybrid/Electric: Hybridization and Electrification	5
Other Powertrain: Alternative Transmissions	30
Other Powertrain: Hydraulic Fluid	70
Other Powertrain: Advanced Diesel Lubricants	5
Other Powertrain: Advanced Transmissions	30
Other Powertrain: Variable Valve Timing	10
Other Powertrain: CVTs	1

Table 5A: Average Market Share for Three Technology Groups Currently In-Market

Technology	Average Current Market Share for "In-market" Technologies
Aero	61%
Hybrid/Electric	23%
Other Powertrain	47%

Table 6 reports the technologies that make up the responses for technologies that are currently in-development and their expected market share in 2015. Companies that reported current market shares of 90 percent or more were withheld due to confidentiality issues. Some technologies show a combined market share over 100 percent. This may be due to errors in reporting or because companies are describing specific technologies within the general topic. Table 6A shows the low levels of market share expected by in-development technologies in 2015. This may reflect the slow adoption pattern companies expect for these technologies.

Table 6: Reported Technologies Currently in-development and Expected Market Share in 2015

In-development Technology	Market Share in 2015
Aero: Active Flow Control	80
Aero: No Touch Designs	30
Aero: Aerodynamic Improvements	2
Hybrid/Electric: Pure Electric Engine	1
Hybrid/Electric: Hybrid Electric Powertrain	8
Hybrid/Electric: Hybrids-Refuse/Military	2
Hybrid/Electric: Hybrid Engines	4
Hybrid/Electric: Electric Auxiliary Accessories	15
Hybrid/Electric: Fuel Cell Engine	75
Hybrid/Electric: Thermoelectric Generators	25
Hybrid/Electric: Electrification of powertrains	60
Hybrid/Electric: Electric Motors and Drive Electronics	5
Hybrid/Electric: Pure electric vehicle	40
Hybrid/Electric: APU Anti-Idling	50
Hybrid/Electric: Pure Electric and Hybrid Powertrains	23
Hybrid/Electric: Hybrid Engines	15
Hybrid/Electric: Energy Storage Systems	20
Hybrid/Electric: Energy storage electric controls	30
Hybrid/Electric: Hybridization and Electrification	1
Other Powertrain: Engine downsizing including turbo compounding	20
Other Powertrain: Bottom Cycling	38
Other Powertrain: Tuned axles	8
Other Powertrain: Advanced Friction Technologies	8
Other Powertrain: Mechanical Automatic Transmissions	50
Other Powertrain: Bottom cycling	1
Other Powertrain: Waste Heat Recovery Designs	25
Other Powertrain: Hydraulic launch for Diesel Engines	1
Other Powertrain: Axle and Brake Optimized	35

Table 6A: Average Predicted Market Share for Three Technology Groups in 2015 that are Currently In-Development

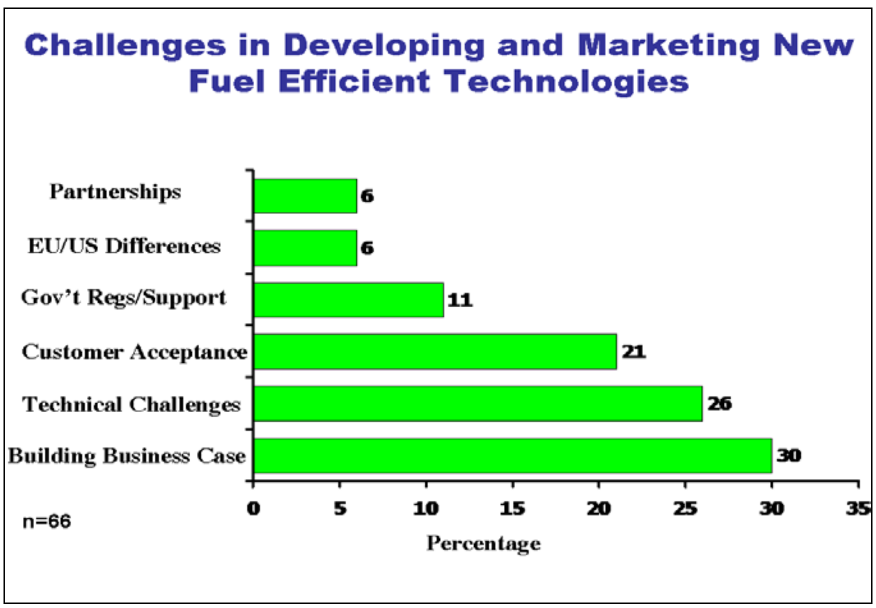
Technology	Average 2015 Market Share for "In-development" Technologies
Aero	37%
Hybrid/Electric	22%
Other Powertrain	23%

Challenges in Developing and Marketing New Fuel Efficient Technologies

The executives who took part in our research provided us with significant insight into the challenges they face in developing and marketing new fuel efficient technologies. Figure 2 shows their 66 responses grouped into 6 groups. The main challenge reported focuses on building the business case for developing the new technologies. A number of executives report a dearth of R&D funding and the large amount of capital investment needed for development. One executive provided key elements of building a business case in this industry.

> The truck market wants reliability as the single most important factor, even above fuel efficiency. They are very reluctant to buy new technologies. Tied to reliability are maintenance costs. Finally, there is resale value. If the second user doesn't value the technology then the money initially paid is not recovered.

Figure 2: Challenges in Developing and Marketing New Fuel Efficient Technologies



Technical challenges are the next most mentioned challenge. These technical challenges cross a number of technologies including fuel stack durability, uncertain material choices, the cost of energy storage, the weight added by new technologies, bottom cycling, and durability and control functions for transmissions.

Customer acceptance also rated high on the list of challenges. Executives report a variety of customer acceptance issues. They see the need for a clear value proposition for their customers centered on a two year payback. This payback timeframe was mentioned by a number of executives throughout the interviews. Though it seems like a short period of time, it is tied to the best time for fleets to turnover their vehicles to maximize a vehicle's resale value. Though companies tend to hold their vehicles for 3-4 years, they want a couple of years of savings before selling the vehicle. Yet another executive told a different story about how major fleets turnover their fleets.

> It used to be 3-4 years for most major fleets to turnover their vehicles. In last 3 years, we've seen it expand. Technology and emissions requirements have added $25K additional cost. Fleets are stretching out the time horizon to about 4-5 years. The value equation is the initial purchase price, the resale value, and maintenance cost during the vehicle's life with the company.

For government support challenges, executives report the lack of long term consistency in support of new technology, the need for government financial support for R&D, and the hope that the government lets the best technology win rather than mandating a particular technology. Executives reported one major difference between the two production systems in the US and the EU. In the US, the production system is more customer focused, which demands high customization and assembly flexibility; whereas, in the EU the manufacturer controls most of the decisions on vehicle configuration, similar to the light vehicle market in the U.S.

Finally, a few executives remarked that they had trouble in finding partners to share the cost of development of new technologies, and that some of the larger companies were trying to push out some of the smaller companies in order to control development.

Some of these challenges come as no surprise to anyone who follows new technology development, but the medium/heavy truck industry has some unique business components that make the introduction of new technologies more challenging.

Revenues from New Technologies

Current Revenues: Technologies In-market and In-development

Our focus on the current and future jobs related to these technologies is related to the revenues companies gain from the introduction of these technologies. For our sample of 52 technologies, the average annual revenue for all technologies that are currently in the market is about $39 million, and the expected average annual revenue for 2015 for all the technologies that are in-development will be about $200 million. This optimism about future technologies may also explain the higher than expected reports of revenues and jobs about these technologies. The optimism may be based on expected future regulation or the fuel economy gains the technologies can provide or both regulation and gains. These results are to be expected when asking people about an uncertain future.

When we examine the current revenues for the 28 technologies in the market by the three categories of technology and the estimated 2015 revenues for the 35 technologies in-development in Table 7, we see much larger average revenues for Hybrid/Electric and Other Powertrain technologies than for Aero technologies. This is expected considering the lower cost of Aero technologies compared to most of the other technologies. It is interesting that executives expect that the Other Powertrain technologies will provide more revenue than the

Hybrid/Electric technologies for the in-development group, while the in-market group thinks that currently Hybrid/Electric technologies average more revenue than the Other Powertrain technologies. This may be because of higher optimism for the Other Powertrain technologies or lower optimism for the Hybrid/Electric technologies.

Table 7: Average Revenues for Three Categories of Technologies "In-market" (Current) and "In-development" (2015)

Technology	Average Current Revenue for "In-market" Technologies (Million$)	Average 2015 Revenue for "In-development" Technologies (Million$)
Aero	.83	28.3
Hybrid/Electric	51.3	152.0
Other Powertrain	45.2	366.0
Average Total	40.6	200.0

Future Revenues: Technologies In-market and In-development

To establish future revenues for the three technology groups, we asked executives to look out over the next 10 years and estimate what a low and high growth rate would be for their particular technology, whether it was in-market or in-development. The overall average for the low growth scenario for all the technologies combined is $109 million for technologies in-market and $306 million for technologies in-development, a significant difference. Again, expectations for in-development technologies within a low growth scenario are significantly higher than the expectations for the in-market technologies, as seen in Table 8. According to the executives in this survey, the Other Powertrain technologies offer more potential revenue, even in this low growth scenario.

Table 8: Average Revenues for Three Categories of Technologies "In-market" and "In-development" for Low Growth Scenario

Technology	Average 2020 Revenue for "In-market" Technologies: Low Growth Scenario (Million$)	Average 2020 Revenue for "In-development" Technologies: Low Growth Scenario (Million$)
Aero	1.5	49.4
Hybrid/Electric	95.4	282.0
Other Powertrain	174.0	454.0
Average Total	109.0	306.0

The overall average for the high growth scenario for all the technologies combined is $221 million for technologies in-market and $595 million for technologies in-development, a significant difference. Again, expectations for in-development technologies within a high growth scenario are significantly higher than the expectations for the in-market technologies, as seen in Table 9. According to the executives in this survey, the Other Powertrain technologies offer more potential revenue in this low growth scenario. But the difference between Hybrid/Electric and Other Powertrain technologies is not as great as in the low growth scenario.

All of these reports show the slow introduction of these technologies in the market today and the potential that companies see for them.

Table 9: Average Revenues for Three Categories of Technologies "In-market" and "In-development" for a High Growth Scenario

Technology	Average 2020 Revenue for "In-market" Technologies: High Growth Scenario (Million$)	Average 2020 Revenue for "In-development" Technologies: High Growth Scenario (Million$)
Aero	14.7	54.9
Hybrid/Electric	229.0	652.0
Other Powertrain	302.0	678.0
Average Total	221.0	595.0

Jobs from New Technologies

To establish the number of jobs that would be created if the new technologies companies have developed or are developing reach their low or high growth scenarios, we asked executives to estimate how many jobs would be added for each scenario across the main categories of Research and Development (R&D), Manufacturing, Sales and Marketing, and Other Jobs such as administrative, aftermarket, or dealer sales/service. Some executives could only estimate the total number of jobs, so our responses by category of job are not as complete as the total number of jobs. One category that seemed to vary substantially is the Other Jobs category. Some executives included large numbers of jobs outside their companies in the areas of aftermarket and dealer sales/service. While some technologies most certainly will increase jobs in these areas, the estimates of the number of jobs that will be created outside a company are probably less reliable than the jobs inside the company.

Current Jobs: Technologies In-market and In-development

Our analysis of current jobs related to the technologies yielded some interesting results. For our sample of 52 technologies, the average number of jobs related to all technologies that are currently in the market is about 97, while the average number of jobs for technologies that are in-development is about 100.

When we examine the current jobs for the 52 technologies in the market and in-development by the three categories of technology in Table 10, we see more jobs related to Hybrid/Electric than Other Powertrain technologies. But the major difference is in the Aero technologies where one large company is putting a very large development effort into these technologies. Because there are only a few aerodynamics technology projects reported, this one company dominates the average. (The median number of jobs for this group is 18, which is similar to the average for in-market aero technologies.)

It is interesting that executives see Hybrid/Electric technologies providing more jobs than the Other Powertrain technologies. This is the opposite of what we saw for current revenues from the technologies.

Table 10: Average Number of Current Jobs for Three Categories of Technologies "In-market" and "In-development"

Technology	Average Number of Current Jobs for "In-market" Technologies	Average Number of Current Jobs for "In-development" Technologies
Aero	18	636
Hybrid/Electric	44	47
Other Powertrain	64	26
Average Total	97	100

When we examine the number of current jobs by the different job categories in Table 11, we see a larger number of Manufacturing jobs, but a significant number of Other Jobs such as administrative, aftermarket, and dealer sales/service. Because of the fragmented nature of the medium/heavy production and assembly process with multiple companies taking part in assembling the final product, the Other Jobs category plays an important role in how companies view the role of other companies. What is not clear is if they actually know how many jobs will be added in other companies because of the new technologies.

One executive remarked about the increase in manufacturing jobs compared to other types of jobs.

> Manufacturing will be fairly linear, but other areas will not be as linear because our technology is an adaptation of existing products and markets so there is no need to create more jobs.

But another executive described the savings a company gains when moving from R&D to manufacturing.

> Overhead, indirect and G&A for R&D is much more than manufacturing. As we transfer from R&D to Manufacturing we save 45 percent per job.

Table 11: Average Number of Current Jobs Across Job Categories

Function	% of Current Jobs
R&D	21%
Manufacturing	44%
Sales and Marketing	5%
Other	30%
Total	100%

When we look at current jobs across different job categories that are in-market or in-development in Table 12, executives report some major discrepancies between the in-market and in-development technologies. In general, executives report that Sales and Marketing tend to have fewer jobs than other categories. As one executive stated,

> I think from here to the first $20 million, most will go into jobs. From $20 million to $100 million, you need infrastructure and capital. The curve will flatten out. It will be pretty linear but the types of jobs will change. You don't need as many Sales and Marketing jobs. Selling $1 billion is the same as $100 million because of the low number of customers in the trucking industry.

One must remember that not all of the companies developing these new technologies are manufacturing companies. A number of the companies in the sample are engineering R&D companies that only plan to develop the technology and outsource the manufacturing of the product.

It is striking that the in-development technologies would have fewer jobs percentage-wise in R&D, Manufacturing, and Other Jobs than in-market technologies. It may be that the current in-development technologies are closer to being brought to market than is generally expected.

Table 12: Percentage of Current Jobs within Four Job Categories for "In-market" and "In-development" Technologies

Function	% Current Jobs for "In-market" Technologies	% Current Jobs for "In-development" Technologies
R&D	40%	13%
Manufacturing	31%	47%
Sales and Marketing	10%	4%
Other	19%	36%
Total	100%	100%

Future Jobs: Technologies In-market and In-development

The estimates for future jobs are based on executive responses questions about the number of jobs that would be created in low and high growth revenue scenarios for each of their new technologies, whether they were in-market or in-development.

<u>The Low Growth Scenario</u>
The average number of jobs that would be created in the low growth scenario for all technologies is 113 for in-market technologies and 273 for in-development technologies. Similar to the revenue analysis, the technologies that are in-development are expected to employ more people than are technologies that are in-market, as seen it Table 13. This result emphasizes the lower level of work for in-market technologies compared to the potential for in-development technologies.

The in-market Hybrid/Electric technologies are expected provide more jobs than the other two technologies in the low growth scenario, while Aero technologies are predicted to provide the most jobs in the in-development group. Similar to the current jobs analysis the major difference is in the Aero technologies where one large company is putting a very large development effort into these technologies. Because there are only a few aerodynamics technology projects reported, this one company dominates the average. (The median number of jobs for this group is 81, which is similar to the average for in-market aero technologies.)

Table 13: Average Number of Jobs for Three Categories of Technologies "In-market" and "In-development" for Low Growth Scenario

Technology	Average Number of Jobs for "In-market" Technologies: Low Growth Scenario (Million$)	Average Number of Jobs for "In-development" Technologies: Low Growth Scenario (Million$)
Aero	65	734
Hybrid/Electric	151	287
Other Powertrain	87	70
Average Total	113	273

When we examine the number of jobs in the low growth scenario by the different job categories in Table 14, we see a similar pattern to the current jobs by job categories. Most of the jobs are in Manufacturing followed by Other Jobs (such as administration, aftermarket, and dealer sales/service) and R&D, and fewer jobs in Sales and Marketing. As noted earlier, the Other Jobs category plays an important role in how companies view the role of other companies. What is not clear is if they actually know how many jobs will be added in other companies because of the new technologies.

Table 14: Percentage of Jobs Across Job Categories in a Low Growth Scenario

Function	% of Jobs: Low Growth Scenario
R&D	23%
Manufacturing	46%
Sales and Marketing	6%
Other	25%
Total	100%

When we look at the jobs in the low growth scenario across different job categories that are in-market or in-development in Table 15, the percentages are similar between the in-market and in-development groups of technologies. Manufacturing jobs make up a somewhat larger percentage of jobs in the in-development group than in the in-market group, which may mean that in a low growth scenario, the in-development technologies are closer to being brought to market than is generally expected.

Table 15: Percentage of Jobs within Four Job Categories for "In-market" and "In-development" Technologies: Low Growth Scenario

Function	% Jobs for "In-market" Technologies: Low Growth Scenario	% Jobs for "In-development" Technologies: Low Growth Scenario
R&D	28%	20%
Manufacturing	36%	49%
Sales and Marketing	12%	4%
Other	24%	27%
Total	100%	100%

<u>The High Growth Scenario</u>
The average number of jobs that would be created in the high growth scenario for all technologies is 209 for in-market technologies and 544 for in-development technologies. Similar to the revenue analysis, the technologies that are in-development are expected to employ more people than are technologies that are in-market, as shown in Table 16. This result emphasizes the lower level of work for in-market technologies compared to the potential for in-development technologies.

The in-market Hybrid/Electric technologies are expected provide more jobs than the other two technologies in the low growth scenario, while Aero technologies are predicted to provide the most jobs in the in-development group. Similar to the current and low growth jobs analysis the major difference is in the Aero technologies where one large company is putting a very large development effort into these technologies. Because there are only a few aerodynamics technology projects reported, this one company dominates the average. (The median number of jobs for this group is 213, which is more in line with the average for in-market aero technologies.)

Table 16: Average Number of Jobs for Three Categories of Technologies "In-market" and "In-development" for High Growth Scenario

Technology	Average Number of Jobs for "In-market" Technologies: High Growth Scenario	Average Number of Jobs for "In-development" Technologies: High Growth Scenario
Aero	139	811
Hybrid/Electric	276	697
Other Powertrain	157	119
Average Total	209	544

When we examine the number of jobs in the low growth scenario by the different job categories in Table 17, we see a similar pattern to the current and low growth jobs by job categories, except that Manufacturing is predicted to have a higher percentage of jobs. Most of the jobs are in Manufacturing followed by Other Jobs (such as administration, aftermarket, and dealer sales/service) and R&D, and fewer jobs in Sales and Marketing. As noted earlier, the Other Jobs category plays an important role in how companies view the role of other companies. What is not clear is if they actually know how many jobs will be added in other companies because of the new technologies.

Table 17: Percentage of Jobs Across Job Categories in a High Growth Scenario

Function	% of Jobs: High Growth Scenario
R&D	16%
Manufacturing	59%
Sales and Marketing	6%
Other	19%
Total	100%

When we look at the jobs in the high growth scenario across different job categories that are in-market or in-development in Table 18, the percentages are similar between the in-market and in-development groups of technologies. Manufacturing jobs make up a somewhat larger percentage of jobs in the in-development group than in the in-market group, which may mean that in a high growth scenario, the in-development technologies are closer to being brought to market than is generally expected.

Table 18: Percentage of Jobs within Four Job Categories for "In-market" and "In-development" Technologies: High Growth Scenario

Function	% Jobs for "In-market" Technologies: High Growth Scenario	% Jobs for "In-development" Technologies: High Growth Scenario
R&D	20%	14%
Manufacturing	47%	63%
Sales and Marketing	10%	4%
Other	23%	19%
Total	100%	100%

New, Retained, and Lost Jobs: Refining Job Creation

For each of the technologies reported by executives, we asked what percentage of the total number of jobs created over the next 10 years would be new jobs, retained jobs, or lost jobs (possibly due to producing outside the U.S.). These questions offer important insights into how executives view jobs within their companies and also the role outsourcing will play in the production of these technologies.

Looking at the overall distribution of new, retained, and lost jobs because of the new technologies in Table 19 we see that 100 percent of the companies report that the jobs created by the new technologies will either be new jobs or retained jobs. Also, for the companies reporting new jobs, the average percentage of new jobs per company was 59 percent. For companies reporting retained jobs, the average percentage of retained jobs per company was 41 percent. There is very little difference between in-market and in-development technologies concerning new, retained, or lost jobs.

Table 19: Percentage of New, Retained, and Lost Jobs from the Introduction of New Technologies

Type of Job	Percentage of Jobs
New Jobs	59%
Retained Jobs	41%
Lost Jobs	0%
Total	100%

When looking at the percentage of new, retained, and lost jobs across the three technology categories in Table 20, we see only a couple differences. Hybrid/Electric technologies are expected to provide more new jobs, and Other Powertrain technologies are expected to provide more retained jobs.

Table 20: Percentage of New, Retained, and Lost Jobs for Three Categories of Technologies

Technology	% of New Jobs	% of Retained Jobs	% of Lost Jobs
Aero	63%	37%	0%
Hybrid/Electric	72%	28%	0%
Other Powertrain	55%	45%	0%
Average Total	65%	35%	0%

Executives report that the recent recession forced their companies to reduce labor in their plants, and they see these new technologies as a potential opportunity to bring back some of the people that were laid off during the recession. We also asked executives if they see this pattern changing as the market grows. Most did not see the pattern changing, but there were some interesting responses concerning topics related to this question. For example, one executive talked about how growth will change the distribution of new and retained jobs.

> With the new technology, as the market grows, the low growth scenario will be 50/50 with new and retained jobs, but with a high growth scenario it will be 70 percent retained jobs and 30 percent new jobs. We become more efficient as we increase capacity.

A couple of executives questioned the potential growth in jobs because they see their new technologies replacing current technology, not adding new volume. This represents another form of “retained” jobs, where a new technology manufactured in the U.S. keeps jobs that risk going offshore if demand replaces current technology.

> It is not all incremental growth as it will replace our current product lines, so it won't create new jobs for all areas.

On the question of how truck purchasing patterns affect volume and the introduction of new technology, one executive reported,

> Fleets no longer buy heavy duty diesel trucks like before but drive them much longer. Because of legacy fleets they pre-buy and replace just the trailers and engines without buying new trucks.

Finally, the issue of off shoring brought up two conflicting views of labor and new technology introduction.

> The cost of labor in the US and China will become the same because of automation. It will bring back jobs to the US.
>
> There may be some job loss due to global suppliers and a need to have development where companies that are providing the components are housed.

Outsourcing: The Extended Supply Chain

For each of the technologies reported, we asked executives what percentage of manufacturing would be performed within their company and what percentage would be performed outside their company. The average for light vehicle manufacturing tends to be 60 percent inside and 40 percent outside. Our sample of companies reports almost the reverse in Table 21, with 41 percent manufactured inside and 59 percent manufactured outside.

Table 21: Percentage of New Technologies Manufactured Inside and Outside a Company

Place of Manufacture	Percentage of Manufacturing
Inside the Company	41%
Outside the Company	59%
Total	100%

Some of this difference may be because of the type of companies that make up our sample. Forty-six percent of our sample is made up of smaller companies (based on revenues). An analysis comparing the percentage of new technologies manufactured inside and outside a company by size of company in Table 22 shows that the smaller companies indeed expect to outsource more of their manufacturing than the larger companies. These smaller companies are focusing on particular technologies that they expect to sell to the larger companies, rather than manufacture them.

Table 22: Percentage of New Technologies Manufactured Inside and Outside a Company by Size of Company

Place of Manufacture	Percentage of Manufacturing for Companies Under $100 Million in Revenues	Percentage of Manufacturing for Companies Over $100 Million in Revenues
Inside the Company	41%	52%
Outside the Company	59%	48%
Total	100%	100%

Some of these companies are considered Tier 2 suppliers who supply critical parts (such as electronic controllers) of larger systems to Tier 1 suppliers who then sell them to manufacturers. Some of these "parts" may actually be sophisticated computer programs that manage and run the new technologies. Some Tier 2 suppliers also build less complex parts for these new technologies, such as casings, insulation, transistors, wires, or other materials. We have tried to capture some of these companies in our two U.S. maps (Appendix 2 and Appendix 3) of medium/heavy manufacturers and suppliers. Appendix 2 shows the key manufacturers and suppliers involved in the new technologies, while Appendix 3 shows these companies as well as many smaller powertrain suppliers throughout the U.S. who may be supporting the major manufacturers and suppliers. We have purposely been over-inclusive in Appendix 3 in order to show the potential employment effects on the total medium/heavy supply chain.

Both in-market and in-development technologies show the same pattern of outsourcing in Table 23 as the overall sample, but in-development technologies are predicted to be manufactured outside the company even more than in-market technologies.

Table 23: Percentage of Manufacturing Inside and Outside a Company for "In-market" and "In-development" Technologies

Place of Manufacture	% Manufacturing for "In-market" Technologies	% Manufacturing for "In-development" Technologies
Inside the Company	46%	37%
Outside the Company	54%	63%
Total	100%	100%

Examining the relationship between technology that is manufactured inside or outside the company and the type of technology in Table 24 shows that Hybrid/Electric and Other Powertrain technologies tend to be manufactured outside the company while Aero technologies tend to be manufactured inside the company.

Table 24: Percentage of Technologies Manufactured Inside and Outside a Company by Three Categories of Technologies

Technology	% Manufactured Inside the Company	% Manufactured Outside the Company
Aero	54%	46%
Hybrid/Electric	37%	63%
Other Powertrain	41%	59%
Average Total	41%	59%

Measuring Potential Job Growth Related to New Technologies[6]

Current Number of Jobs by Technology Group

Estimating the current number of jobs related to the three technology groups is difficult for four reasons: 1) Because executives reported on a variety of technologies in each technology group, the total number of jobs for their technology may differ greatly from another technology in the same group. 2) There are no government statistics about employment for these technologies or technology groups that can be used to define the number jobs for each group or technology. The government statistics are not refined enough to gather information on these technologies. 3) Many of these technologies are still in development or in the very early stages of deployment, so the baseline employment numbers for the technologies or groups are still relatively low. 4) Generating a number that estimates current employment for these technologies demands sampling all the possible technologies that make up each group. This was not possible for our survey, though it does represent most of the technologies.

Our estimate for the current number of jobs related to each of the three technologies groups is based on the current jobs reported by executives for technologies in our sample that are in-market and in development. Table 25 shows the results of multiplying the total number of jobs reported for each technology by 100/Average Market Share for that technology. For in-market technologies 115 jobs are currently related to aerodynamic technologies, 2,109 jobs related to Hybrid/Electric technologies, and 1,315 jobs related to Other Powertrain technologies.

[6] It is important to note that our estimates of both current and future jobs are limited by the data and modeling inputs. Current and future job estimates are confined to three major technology areas (aerodynamics, hybrid/electric, and other powertrain) and do not take into account possible job growth in other advanced technology areas such as weight reduction and tires. Furthermore, for the current job estimates, our analysis is limited to specific technologies within the three major technology categories for which data was available. The current job estimates therefore present a representative but conservative snapshot of all jobs tied to advanced truck aerodynamics, hybrid/electric, and other powertrain improvements.

Table 25: Current Number of Jobs Related to Three "In-Market" Technology Groups

Technology	Number of Jobs Reported in Survey	Average Market Share	Total Number of Current Jobs
Aero	70	61%	115
Hybrid/Electric	485	23%	2,109
Other Powertrain	618	47%	1,315
Total			3,538

In-development technologies also contribute to current jobs. We have an estimate of current jobs for technologies that are in-development, but we cannot estimate jobs for these technologies in the rest of the market because the technologies in the study do not have a current market share that is used to create the market share for the rest of the market. One option is to use the same average market share used for the in-market technologies. Table 26 shows the results of multiplying the total number of jobs reported for each technology by 100/Average Market Share for that technology. For in-development technologies 3,130 jobs are currently related to aerodynamic technologies, 3,813 jobs related to Hybrid/Electric technologies, and 447 jobs related to Other Powertrain technologies.

Table 26: Current Number of Jobs Related to Three "In-Development" Technology Groups

Technology	Number of Jobs Reported in Survey	Average Market Share	Total Number of Current Jobs
Aero	1,909	61%	3,130
Hybrid/Electric	877	23%	3,813
Other Powertrain	210	47%	447
Total			7,389

Table 27 shows the estimated number of current for each technology group whether the technologies are in-market or in-development.[7]

Table 27: Current Number of Jobs Related to Three Technology Groups

Technology	Total Number of Current Jobs
Aero	3,244
Hybrid/Electric	5,922
Other Powertrain	1,762
Total	10,928

[7] These estimates include reported jobs across research and development, manufacturing, sales and marketing, and other areas. The other areas include administrative, as well as aftermarket and dealer sales/service outside the companies.

Estimates of Incremental Future Jobs By Technology Group

This section presents UMTRI's estimates of future incremental jobs created by the introduction of technologies to improve medium- and heavy-duty truck emissions and fuel economy. The estimates of jobs added described in this section were derived from a top-down analysis of the overall medium- and heavy-duty truck and trailer manufacturing industry at the U.S. national level. Inputs to the analysis include the industry baseline total employment (including suppliers), total revenue (value of shipments), and UMTRI's estimates of productivity trends. Other inputs were the predicted change in revenues for truck and trailer manufacturers under alternative scenarios (from the Union of Concerned Scientists (UCS) predictions of investments in new technologies needed) and UMTRI's estimates of incremental jobs per million dollars of incremental revenue. These job estimates are incremental from today's baseline, and we do not attempt to quantify jobs retained that may be lost if companies based outside the U.S. take the lead on these technologies, as has happened to a certain degree in light duty vehicles.

For this analysis, UMTRI defined the overall medium- and heavy-duty truck and trailer manufacturing industry at the U.S. national level as the combination of two North American Industry Classification System (NAICS)[8] six-digit industries: Heavy Duty Truck Manufacturing (336120) and Truck Trailer Manufacturing (336212).

NAICS Revenue

Table 28 shows the percent of revenue breakdown of NAICS 336120 into its seven-digit members. Both medium (14,001 to 33,000 pounds GVW) and heavy (33,001 pounds and more GVW) trucks are included, but so are buses and other vehicles not specified by kind. Medium and heavy trucks account for 76 percent of NAICS 336120's revenue. We are constrained for most of our analysis to the six-digit NAICS level.

Table 28: NAICS Medium and Heavy Duty Percent of Revenue

		Percent of Revenue	
336120	**Heavy duty truck manufacturing**		**100%**
3361201	Trucks/tractors/bus chassis (chassis own mfg.), 14,001-33k lb	23%	
3361202	Trucks/tractors/bus chassis (chassis own mfg.), 33,001 lb/more	53%	
	Trucks 14,001 lb or more		**76%**
3361203	Buses (chassis own mfg.), incl. military/firefighting vehicles	21%	
	Buses		**21%**
336120W	Heavy duty truck manufacturing, nsk, total	3%	
	Not specified by kind		**3%**

Medium and heavy duty trucks account for 76 percent of NAICS 336120.
The breakdown above is not available for the historical data 1958-2005.
The breakdown above is also not available for a number of key variables used in our analysis.

[8] NAICS stands for North American Industry Classification System, the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. The data are based on the U.S. Census Bureau's 2007 Survey of Business Owners.

NAICS Employment

Total employment in the two 6-digit NAICS industries that constitute the truck and trailer manufacturing industry was just under 59,000 in 2007. Employment averaged 60,300 in 1998 to 2007. Total revenue of the two 6-digit NAICS industries was $26.8 billion in 2007, $37.6 billion in 2006, and averaged $25.0 billion during the 1998-2007 time period (all measured in 2007 dollars).

UMTRI estimated employment of suppliers to 336120 and 336212 using information on the value of shipments of products from the 2007 U.S. Economic Census. We included all motor vehicle 6-digit NAICS industries (336111-336999) and 333618 "Other engine equipment manufacturing" (the supplier of diesel engines for medium and heavy duty trucks). We assumed that the fraction of employees in the supplying industry who support medium and heavy-duty truck and trailer manufacturing was equal to the fraction of the supplying industry's shipments (in dollar value) to 336120 and 336212. This approach yielded an estimate of 107,029 employees in the final industries and their suppliers, as shown in Table 29.

Table 29: NAICS Medium and Heavy Truck Employment

NAICS 2007 6-Digit Code	NAICS 2007 Industry Name	HD Truck & Truck Trailer Employees	Supplier Employees	Total Employees
336111	Automobile manufacturing	0	2,191	2,191
336112	Light truck and utility vehicle manufacturing	0	0	0
336120	**Heavy duty truck manufacturing**	**28,694**	**0**	**28,694**
336211	Motor vehicle body manufacturing	0	10,527	10,527
336212	**Truck trailer manufacturing**	**29,191**	**0**	**29,191**
336213	Motor home manufacturing	0	0	0
336214	Travel trailer and camper manufacturing	0	0	0
336311	Carburetor, piston, piston ring, and valve manufacturing	0	0	0
336312	Gasoline engine and engine parts manufacturing	0	0	0
336321	Vehicular lighting equipment manufacturing	0	0	0
336322	Other motor vehicle electric equipment mfg.	0	1,505	1,505
336330	Motor vehicle steering and suspension parts	0	1,285	1,285
336340	Motor vehicle brake system manufacturing	0	20,548	20,548
336350	Motor vehicle transmission and power train parts manufacturing	0	2,904	2,904
336360	Motor vehicle seating and interior trim manufacturing	0	275	275
336370	Motor vehicle metal stamping	0	1,221	1,221
336391	Motor vehicle air-conditioning manufacturing	0	0	0
336399	All other motor vehicle parts manufacturing	0	0	0
333618	Other engine equipment manufacturing (diesel included)	0	8,689	8,689
		57,885	**49,144**	**107,029**

NAICS Motor Vehicle Manufacturing includes the six-digit industries 336111-336999.

NAICS 333618 is included above because it covers firms that manufacture diesel engines for heavy duty trucks.

NAICS Trends in Employment to Revenue Ratios
The medium/heavy truck industry has seen significant improvement in productivity as seen in Figures 3-5 that show the number of production workers per million dollars of revenue. These analyses formed the basis for our productivity adjustments for our job estimates. Figure 3 shows the productivity gains over the past 50 years based on our analysis of the North American Industry Classification System (NAICS) codes for heavy duty truck manufacturing (336120).

Figure 3: Production Workers per Million Dollars of Revenue for Heavy Duty Truck Manufacturing

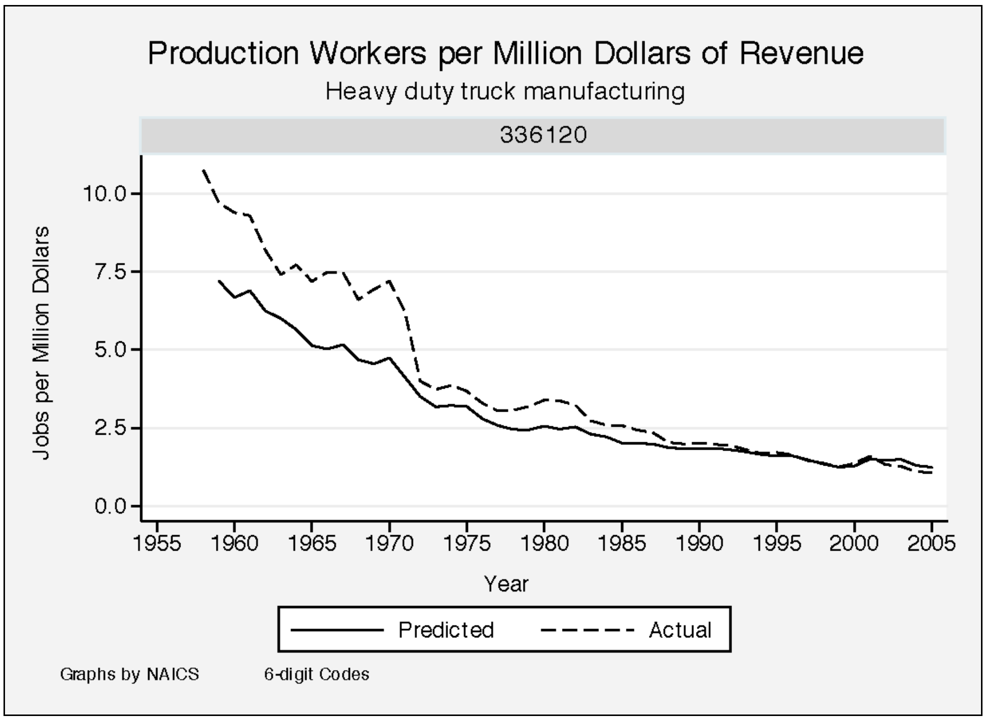


Figure 4 shows the productivity gains for truck trailer manufacturing from our analysis of the NAICS truck trailer manufacturing code 336212.

Figure 4: Production Workers per Million Dollars of Revenue for Truck Trailer Manufacturing

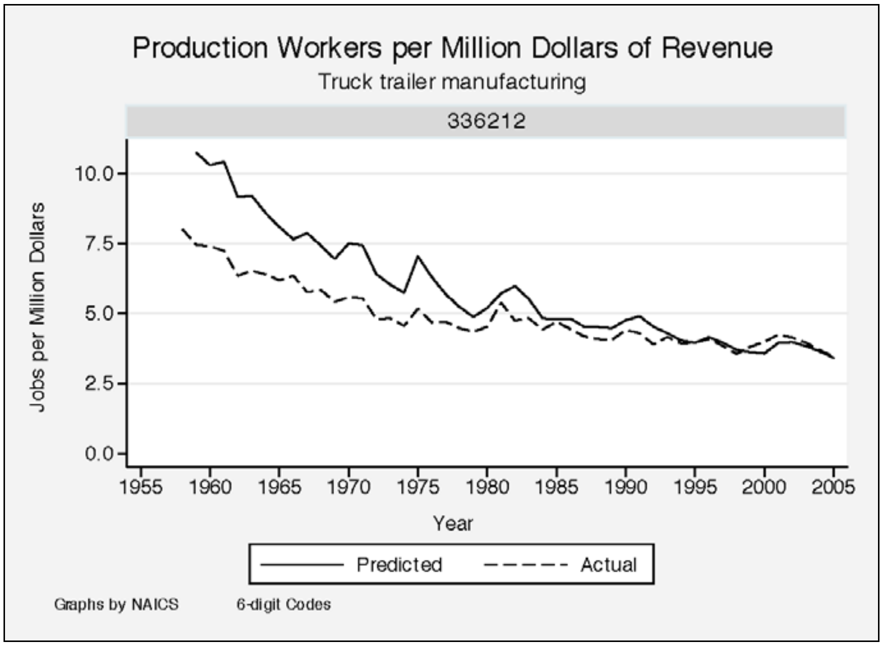
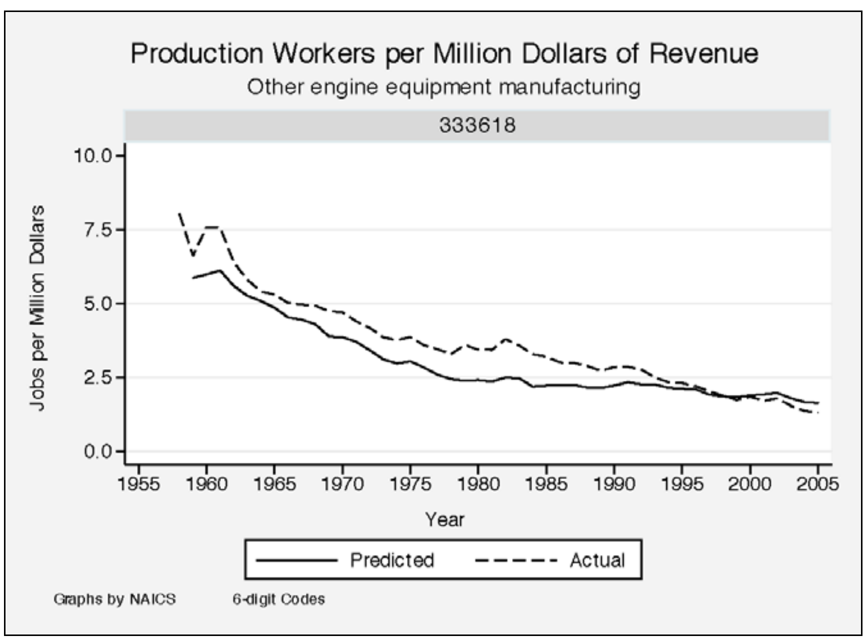


Figure 5 shows our analysis of the productivity gains for other engine manufacturing from the NAICS code 333618.

Figure 5: Production Workers per Million Dollars of Revenue for Other Engine Equipment Manufacturing



The analysis of productivity gains over time and from increasing scale can be summarized by adjustment factors that we multiply by our baseline estimates of jobs per million dollars of revenue for each technology. These baseline estimates of jobs per million dollars of revenue were developed using current information from the survey. The adjustment factors, shown in Table 30, incorporate the reduction in this ratio from now through 2020 and 2030. They are multiplied by the baseline estimates of jobs per million dollars of revenue to adjust them downward to account for growth in productivity over time and increases in productivity with scale. For Reference scenarios, we adjust only for productivity growth over time. For Policy scenarios, we adjust for both time and scale.

Table 30: Time and Scale Productivity Factors

Multiplicative Adjustment Factors for Jobs per Million Dollars of Revenue		
Adjustment Due To:	2020	2030
Productivity growth over time	0.78	0.60
Productivity increase with scal	0.85	0.80
Combined	0.66	0.48

Survey Job Estimates

Our analysis of the survey presented earlier in this report is based solely on the average of reported jobs, irrespective of the size of the company. Because these analyses included some very large companies with large expected job growth based on their original company size, the averages for these analyses tend to be heavily affected by these large estimates. In almost all cases the medians are much lower than the mean. But this sample also has a large number of small companies that expect small growth in the number of jobs because they are small to begin with.

In some ways, this sample represents the complex supply chain of small and large companies trying to develop new technologies, sometimes outside the normal automotive supply chain. Electric, fuel cell, and hybrid technologies are outside the comfort zone of many automotive manufacturers and suppliers who have developed powertrain technologies based on mechanical principles for over 100 years. The smaller companies that specialize in these new technologies may not understand the intricacies of volume manufacturing, but they have expertise in doing the R&D work needed to develop these new technologies.

Our goal in this analysis is to estimate the number of jobs per million dollars of revenue based on the estimates of revenues and jobs provided by executives of the companies that are part of this study. We developed estimates for the three technology groups: Aerodynamics (Aero), Hybrid Powertrains and Electric Accessories (Hybrid/Electric), and Other Powertrain technologies (Other Powertrain) in low and high growth scenarios using the 52 technologies provided by executives in the study.

Our analysis, detailed in Appendix 1, provided the estimates we used to develop a range of potential job growth scenarios for the three technology groups. Table 31 shows the difference scores used to create the estimates.

Table 31: Difference Scores for Jobs Per Million Dollars of Revenue by Three Categories of Technologies

Technology	Current to Low	Current to High	Low to High
Aero	7.35	7.44	7.52
Hybrid/Electric	0.90	1.29	1.08
Other Powertrain	0.28	0.32	0.34

The Reference and Policy Scenarios

To more accurately estimate the effects of the adoption of these technologies on future jobs, we combined our estimates with the estimates of the UCS for the dollars of revenue they predict for each of the technologies in two scenarios: The Reference Scenario (Reference)[9], and the Policy Scenario (Policy)[10]. The Reference scenario is based on gradual growth of the new technologies, while the Policy scenario is based on government support for the growth of the technologies. Table 32 shows the UCS revenue estimates for the three technology groups for 2020 and 2030 for the two scenarios.

[9] The input assumptions for the Reference scenario were largely based on the high technology case used in the Department of Energy's Annual Energy Outlook 2008 report, which uses the underlying assumptions for medium and heavy-duty fuel economy technologies from an Argonne National Labs study from 2002 (Vyas, 2002). Technology is only adopted which meets simple payback requirements as specified in the National Energy Modeling System (NEMS) model and is reflective historic adoption rates. Even in the Reference scenario, there is substantial incremental investment in U.S. companies making advanced technologies. We note that a failure on the part of the United States to maintain a leadership position, particularly through such investment, could actually lead to a loss of jobs to overseas companies.

[10] In the Policy scenario, it is assumed that standards to increase fuel economy of trucks are implemented. To model the effect of standards, technology adoption rates were adjusted to meet the technology potential of 7.5 mpg by 2020 and 9 mpg by 2030 for heavy-duty vehicles and 11 mpg by 2020 and 16 mpg by 2030 for medium-duty vehicles.

Table 32: UCS Revenue Estimates for Three Technology Groups for 2020 and 2030 for Two Scenarios

Reference Scenario

Technology	2020 ($ Billion)	2030 ($ Billion)
Aero	$0.92	$2.49
Hybrid/Electric	$0.28	$0.37
Other Powertrain	$1.01	$3.09
Total	$2.21	$5.95

Policy Scenario

Technology	2020 ($ Billion)	2030 ($ Billion)
Aero	$2.63	$5.25
Hybrid/Electric	$1.76	$5.43
Other Powertrain	$2.18	$8.55
Total	$6.57	$19.23

To generate our estimate of potential jobs under the two scenarios (Reference and Policy), we combined the UCS estimates of potential revenue from the three technology groups in Table 32 with the survey estimates in Table 31 and used productivity measures based on time and scale to develop a set of three estimates that form a boundary around potential job numbers. The first set of estimates is based on the Current-Low survey estimates. To calculate these job estimates we multiply the Current-Low survey estimate for a technology group by the UCS revenue estimate for that group. We then multiply that product by a productivity factor that is based on time for 2020 and scale for 2030[11]. Finally, we multiply the final product by 1000 (because the UCS revenue is in billions of dollars and the survey estimates are in millions of dollars) to generate the final job numbers. We also do this for the Current-High and Low-High survey job estimates. Table 33-35 shows the results of jobs for the Current-Low, Current-High, and Low-High estimates.

[11] Our productivity factor based on time and scale was developed through our analysis of 2009 Annual Survey of Manufacturers from the Bureau of the Census.

Table 33: Incremental Job Estimates for Three Technology Groups for 2020 and 2030 under Two Scenarios and Using the Current-Low Job Estimates

Current-Low Survey Estimates

Reference Scenario

Technology	New 2020 Jobs	New 2030 Jobs
Aero	5,274	10,981
Hybrid/Electric	197	200
Other Powertrain	221	519
Total	5,692	11,700

Policy Scenario

Technology	New 2020 Jobs	New 2030 Jobs
Aero	12,816	18,522
Hybrid/Electric	1,050	2,346
Other Powertrain	405	1,149
Total	14,271	22,017

Differences Between Reference and Policy Jobs Estimates

Technology	New 2020 Jobs	New 2030 Jobs
Aero	7,542	7,541
Hybrid/Electric	854	2,146
Other Powertrain	184	630
Total	8,580	10,317

Percentage Increases from Reference to Policy Jobs Estimates

Technology	New 2020 Jobs	New 2030 Jobs
Aero	143%	69%
Hybrid/Electric	434%	1074%
Other Powertrain	83%	121%
Total	151%	88%

Table 34: Incremental Job Estimates for Three Technology Groups for 2020 and 2030 under Two Scenarios and Using the Current –High Job Estimates

Current -High Survey Estimates

Reference Scenario

Technology	New 2020 Jobs	New 2030 Jobs
Aero	5,337	11,112
Hybrid/Electric	283	287
Other Powertrain	252	593
Total	5,872	11,992

Policy Scenario

Technology	New 2020 Jobs	New 2030 Jobs
Aero	12,969	18,743
Hybrid/Electric	1,511	3,375
Other Powertrain	462	1,312
Total	14,942	23,430

Differences Between Reference and Policy Jobs Estimates

Technology	New 2020 Jobs	New 2030 Jobs
Aero	7,632	7,631
Hybrid/Electric	1,228	3,087
Other Powertrain	210	719
Total	9,070	11,438

Percentage Increases from Reference to Policy Jobs Estimates

Technology	New 2020 Jobs	New 2030 Jobs
Aero	143%	69%
Hybrid/Electric	434%	1074%
Other Powertrain	83%	121%
Total	154%	95%

Table 35: Incremental Job Estimates for Three Technology Groups for 2020 and 2030 under Two Scenarios and Using the Low –High Job Estimates

Low-High Survey Estimates

Reference Scenario

Technology	New 2020 Jobs	New 2030 Jobs
Aero	5,396	11,235
Hybrid/Electric	236	240
Other Powertrain	268	630
Total	5,900	12,105

Policy Scenario

Technology	New 2020 Jobs	New 2030 Jobs
Aero	13,113	18,950
Hybrid/Electric	1,260	2,815
Other Powertrain	491	1,395
Total	14,864	23,161

Differences Between Reference and Policy Jobs Estimates

Technology	New 2020 Jobs	New 2030 Jobs
Aero	7,716	7,715
Hybrid/Electric	1,024	2,575
Other Powertrain	224	765
Total	8,964	11,056

Percentage Increases from Reference to Policy Jobs Estimates

Technology	New 2020 Jobs	New 2030 Jobs
Aero	143%	69%
Hybrid/Electric	434%	1073%
Other Powertrain	83%	121%
Total	152%	91%

Examining the job totals for each of the survey estimates and scenarios provides some boundaries for the job estimates under the different scenarios, as shown in Table 36. As expected, the Reference scenario provides fewer jobs than the Policy scenario for all the job estimates. In the Policy scenario, 2.5 times as many jobs are created compared to the Reference scenario in 2020 and over 2 times as many jobs in 2030. Within the Reference scenario, the Low-High job estimates generate the most jobs, while in the Policy scenarios the Current-High job estimates generate the most jobs. But overall, there are few major differences among the estimates within the Reference and Policy scenarios. This range of estimates creates boundaries for estimating the effects of different scenarios on job growth due to the new technologies. Thus the Reference/Policy scenarios in 2020 show job creation ranging from a high of 5,692 jobs (Reference) to 14,942 jobs (Policy), and in 2030, job growth ranges from a high of 11,700 jobs (Reference) to 23,430 jobs (Policy).

Table 36: Job Estimates for Three Technology Groups for 2020 and 2030 under Two Scenarios and Using the Three Survey Job Estimates

Reference Scenario

Survey Estimate	2020 Jobs	2030 Jobs
Current-Low	5,692	11,700
Current-High	5,872	11,992
Low-High	5,900	12,125

Policy Scenario

Survey Estimate	2020 Jobs	2030 Jobs
Current-Low	14,271	22,017
Current-High	14,942	23,430
Low-High	14,864	23,161

Differences Between Reference and Policy Jobs Estimates

Survey Estimate	2020 Jobs	2030 Jobs
Current-Low	8,580	10,317
Current-High	9,070	11,438
Low-High	8,964	11,056

Percentage Increases Between Reference to Policy Jobs Estimates

Survey Estimate	2020 Jobs	2030 Jobs
Current-Low	151%	88%
Current-High	154%	95%
Low-High	152%	91%

Policy Options for Supporting New Technologies

All of the executives who participated in the survey were asked about the effectiveness of a variety of policy options in supporting the development, sale, and use of more fuel efficient trucks. Compared to light vehicles, the government does not need to use as many efforts to convince companies to move in this direction. Company decisions about moving to more fuel efficient trucks are looked at in purely financial terms. If the government can make the case that moving to these vehicles will provide a short term financial reward for the company, it will be easier for the companies to comply. The government has a lot of levers it can pull to support the move to more fuel efficient trucks. Figure 6 shows the ratings for a variety of policy initiatives.

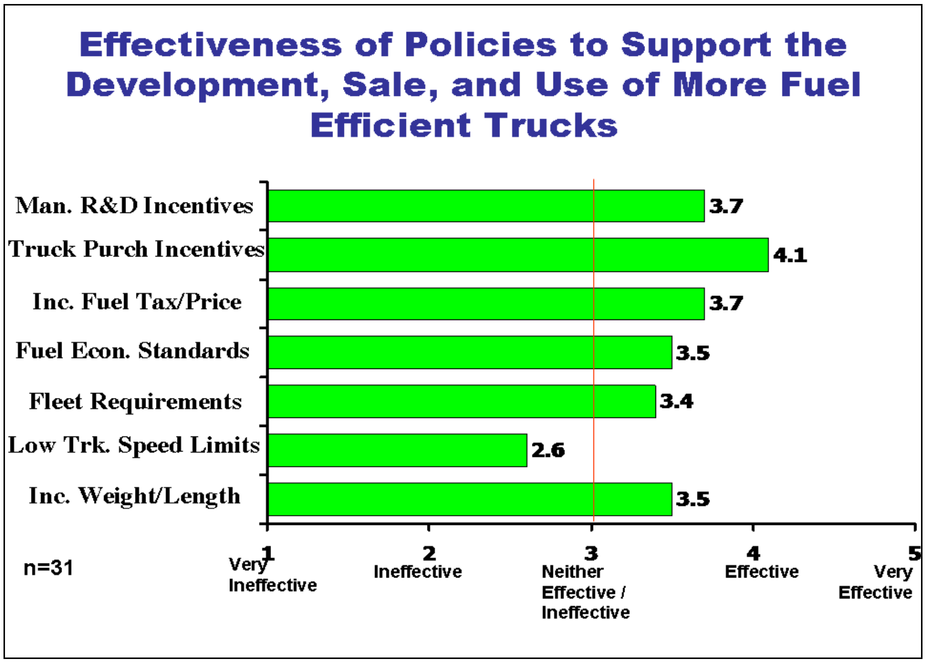
Executives report that truck purchasing incentives, manufacturer R&D incentives, and increases in fuel prices or taxes would be the most effective in supporting the move to more fuel efficient trucks. One can view the truck purchasing incentives as a form of "cash for clunkers" program that would take the most fuel inefficient and most polluting vehicles off the roads completely. Though it would probably be an expensive program, it would show companies that the government is serious about moving to more fuel efficient trucks. Two executives noted that incentive vouchers are more effective than tax credits because some companies lease their trucks. One executive thinks that purchasing incentives have a short term effect, but in the long term it keeps breakthrough technologies from emerging because companies will have already purchased more trucks than they would have because of the incentive.

Manufacturer R&D incentives would support development of technologies that would not only increase fuel economy but also help develop more cost effective technologies. As some of the executives noted, the return on investment on many of these technologies is not yet what it needs to be in order to stimulate widespread adoption. Some of the technologies have an eight year return on investment, while companies are looking at two years as their benchmark. A couple of executives report that the support for R&D is particularly important because some of the companies that are working on these technologies are not yet revenue producing, and they need this support in order to bring new technology to market.

An increase in fuel taxes/prices also would force companies to make important economic decisions about their fleets. It would change the equation companies use to determine the return on investment in a new technology. It would not allay the uncertainty companies would have about introducing new technology into their fleets, but it definitely would force change. The potential negative response to a rise in fuel prices/taxes could be a rise in the prices of goods transported using this fuel, as companies try to pass on the cost increase to consumers instead of changing the powertrain technology of their fleets.

Finally, three executives report that regulating CO2 and greenhouse gas emissions would also, because of the link between CO2 and fuel economy, force companies to move toward more fuel efficient technologies or else pay fines for not reaching certain standards. An unintended consequence of a policy such as this is the buy-ahead process that companies engage in, where companies buy a large number of vehicles that qualify under the old standard just before the new regulation goes into effect.

Figure 6: Effectiveness of Policies to Support the Move to More Fuel Efficient Trucks



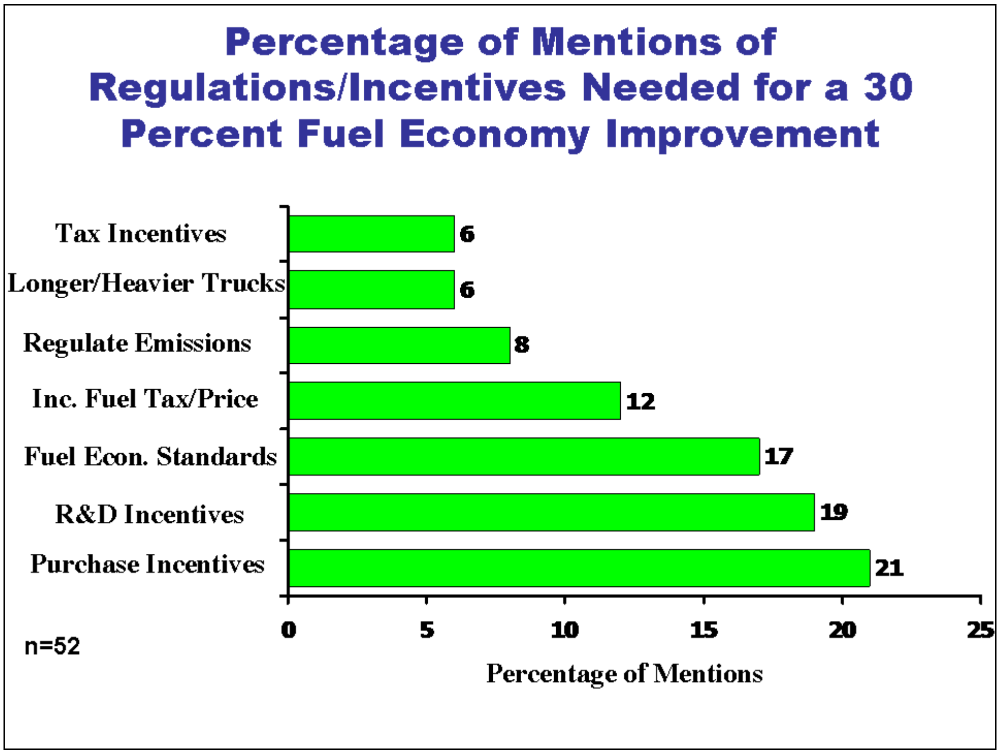
We also asked executives what regulations or incentives would need to be implemented to increase fuel efficiency in the medium/heavy truck fleet by 30 percent. A 30 percent increase in fuel economy is considered a dramatic improvement over current fuel economy, but executives were somewhat consistent with their previous answers on the effectiveness of certain policies, as seen in Figure 7. In order to reach a 30 percent increase in fuel economy, they report that purchase incentives, R&D incentives, fuel economy standards, and an increase in fuel prices/taxes are the main regulatory/incentive actions to be taken.

The need for purchase incentives is driven primarily by the need to support the capital costs involved in purchasing vehicles with the new technologies that are, at present, very expensive. One executive also suggested incentives for retro-fitting the fleet of used vehicles in order to speed the transition to more fuel efficient trucks.

The need for R&D incentives comes from the high cost of developing new technologies. Executives understand the cost involved in this development, and the uncertainty that is part of the development of these new technologies. One executive said they won't do R&D unless the product can be sold, which sets a very high bar for the type of R&D projects a company takes on.

One executive noted that fuel economy standards must be designed carefully because, "If you make it too expensive, it trickles down to the goods that are being shipped." Another executive raised another note of caution to regulators when he stated, "The technologies have to stand on their own. Incentives and regulations are not enough. The customers have to be happy with the technology they are using."

Figure 7: Percentage of Regulations/Incentives for Reaching a 30 Percent Fuel Economy Improvement



Conclusion

There are significant revenues and jobs that can come from the introduction of new fuel efficient technologies in the medium/heavy truck industry. Because many of the technologies are still in development, many of the new jobs are and will be in the higher paying R&D area. But most new jobs as well as some retained jobs will be in the manufacturing area.

But moving to new fuel efficient technologies will not be easy. Fleets and owner-operators are very risk averse, and the new technologies inject a level of uncertainty in terms of return on investment, maintenance, and resale that most companies are not willing to take on. Also, there is an uncertainty in the technologies that are expected to play an important role in the future medium/heavy truck fleet. Some of the technologies are in an early stage of development, while others are already available in the marketplace.

There is less uncertainty in some of the aerodynamic technologies. These technologies not only tend to be less expensive than some of the powertrain technologies, but they offer the opportunity to retrofit existing tractors and trailers, thus speeding the spread of the fuel efficient technologies throughout the entire fleet rather than just the new tractors and trailers.

The role government can play in this transition to more fuel efficient trucks cannot be overstated. Our analyses show a significant amount of revenues and jobs generated through our Policy scenario which includes government support compared to the Business As Usual Approach which does not include government support. Though medium/heavy truck buyers are always interested in saving money through improved fuel efficiency in their fleets, the cost of these new technologies must meet their return on investment criteria, usually around 24 months, before they will invest. The government can, of course, demand that manufacturers build more fuel efficient vehicles or that fleets maintain a certain level of fleet fuel economy through regulations, but these regulations can have unintended consequences the can delay the main goal of a program. To see a large increase in fuel economy, the government may have to use a combination of R&D and purchase incentives as well as regulations to change over the medium/heavy truck fleet to a more fuel efficient fleet.

Appendix 1

Generating estimates of jobs per million dollars of revenue

Our formula for estimating the number of jobs per million dollars of revenue is based on a series of difference scores. We start by summing the separate revenues for Aero, Hybrid/Electric, and Other Powertrain technologies for the current, low, and high scenarios. We then use the same process for the jobs estimated by executives. This provides us with 18 sums. The employment estimates per million dollars of revenue were created using the following formulas for each technology group.

Aero:
Sum of Current Aero Revenue (CAR)
Sum of Aero Revenue: Low Growth Scenario (LAR)
Sum of Aero Revenue: High Growth Scenario (HAR)
Sum of Current Aero Jobs (CAJ)
Sum of Aero Jobs: Low Growth Scenario (LAJ)
Sum of Aero Jobs: High Growth Scenario (HAJ)

Current to Low

$$\frac{LAJ-CAJ}{LAR-CAR} * 1{,}000{,}000 = 3.22$$

Current to High

$$\frac{HAJ-CAJ}{HAR-CAR} * 1{,}000{,}000 = 3.15$$

Low to High

$$\frac{HAJ-LAJ}{HAR-LAR} * 1{,}000{,}000 = 3.08$$

Hybrid/Electric:
Sum of Current Hybrid/Electric Revenue (CHR)
Sum of Hybrid/Electric Revenue: Low Growth Scenario (LHR)
Sum of Hybrid/Electric Revenue: High Growth Scenario (HHR)
Sum of Current Hybrid/Electric Jobs (CHJ)
Sum of Hybrid/Electric Jobs: Low Growth Scenario (LHJ)
Sum of Hybrid/Electric Jobs: High Growth Scenario (HHJ)

Current to Low

$$\frac{LHJ-CHJ}{LHR-CHR} * 1{,}000{,}000 = .77$$

Current to High

$$\frac{HHJ-CHJ}{HHR-CHR} * 1{,}000{,}000 = 1.16$$

Low to High

$$\frac{HHJ-LHJ}{HHR-LHR} * 1{,}000{,}000 = 1.00$$

Other Powertrain:
Sum of Current Other Powertrain Revenue (COR)
Sum of Other Powertrain Revenue: Low Growth Scenario (LOR)
Sum of Other Powertrain Revenue: High Growth Scenario (HOR)
Sum of Current Other Powertrain Jobs (COJ)
Sum of Other Powertrain Jobs: Low Growth Scenario (LOJ)
Sum of Other Powertrain Jobs: High Growth Scenario (HOJ)

Current to Low

$$\frac{LOJ-COJ}{LOR-COR} * 1,000,000 = .27$$

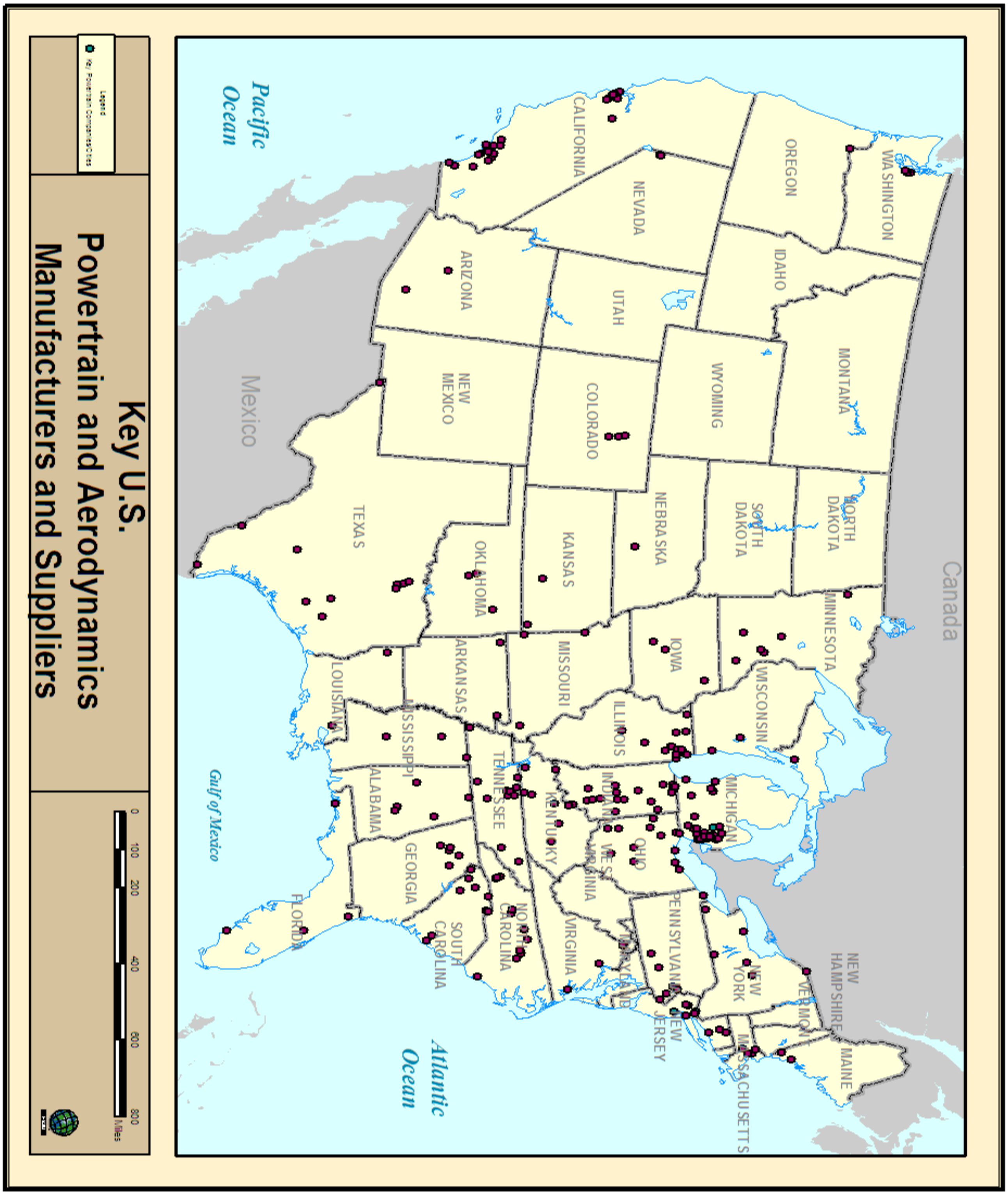
Current to High

$$\frac{HOJ-COJ}{HOR-COR} * 1,000,000 = .31$$

Low to High

$$\frac{HOJ-LOJ}{HOR-LOR} * 1,000,000 = .33$$

Appendix 2: Key Powertrain and Aerodynamics Manufacturers and Suppliers



Appendix 3: Map of All Potential Powertrain and Aerodynamics Companies/Cities