DIESEL POWERS the U.S. ECONOMY

Providing High-Paying Jobs, Exports and Long-Term Productivity Gains in the Nation’s Fundamental Sectors

www.dieselforum.org
DIESEL POWERS THE U.S. ECONOMY:
Providing High-Paying Jobs, Exports and Long-Term Productivity Gains in the Nation’s Fundamental Sectors

Prepared by:
Aspen Environmental Group
M.Cubed

Prepared for:
Diesel Technology Forum

Aspen Environmental Group
8801 Folsom Blvd. Suite 290
Sacramento, CA 95816
(916) 379-0350
ABOUT THIS REPORT

The Diesel Technology Forum (“DTF”) is a non-profit educational association representing diesel engine and equipment and vehicle manufacturers, component suppliers, fuel refiners and emissions control technology manufacturers.

DTF commissioned the California-based research team of Aspen Environmental Group and M.Cubed to undertake this analysis of the importance of diesel power to the U.S. economy. This work also updates a previous effort commissioned by DTF completed in 2000 by Charles River and Associates.

This study is supported by an extensive set of Appendices that, along with this section, comprise the full report. These include:

APPENDIX A: Provision of Diesel Technology: Selling Goods and Services to Diesel Users

- Vehicle Equipment and Engine Manufacturing
- Light-Duty Vehicles: An Emerging U.S. Market
- Fuel Producers, Refiners and Sales
- Oil Production and Refining
- Refining: Volumes, Dollar Values and Trends
- Renewable Diesel Fuels: “Green” Diesel
- Diesel Equipment Sales and Servicing
- Trade and Export In Diesel Technology and Fuel

APPENDIX B: The Economic Benefits of Using Diesel Technology

- Using Diesel to Produce Basic Commodities and Build Infrastructure
- Agriculture: Putting Food on Our Table
- Mining and Construction: Extracting Materials and Building Infrastructure
- Using Diesel to Deliver Goods and Services: Freight Hauling
- Transit: Diesel Moving People Efficiently
- Diesel: A Prime Source of Industrial Site, Remote and Back-Up Power Generation
- Diesel Powers Government
- Military Operations
- State and Local Government
- Public Safety and Protecting Property

APPENDIX C: Existing and Emerging Public Policies Indicate a Strong Future Role for Diesel Technology

- Federal Regulatory Policies
- Influential State and Local Regulations
- Where Is Diesel Headed? Investment in Technology Development and Implementation
- Diesel Industry Research and Development
- Federal R&D Activities
- 21st Century Truck Partnership (2000-2010) and SuperTruck (2011)
- Voluntary Diesel Modernizing and Upgrading (“Retrofit”) Programs
- Federal Funding Programs
- Diesel Emission Reduction Act (DERA)
- Congestion Mitigation and Air Quality Improvement Program (CMAQ)
- Environmental Quality Incentives Program (EQIP)
- State and Local Funding Programs
- California Efforts

APPENDIX D: Methodology: How Is Economic Activity Engendered by Diesel Technology Measured?

- How Is Economic Activity Engendered by Diesel Technology Measured?
- The Concept of Total Output, Value Added and Gross Domestic Product
- Value Added and the GDP, Input-Output Modeling – Briefly
- Diesel Industry Proportional Influence Measurements
- Industry Data Available in Literature
- IMPLAN Relationship Matrices

The full study, including Appendices, is available at www.dieselforum.org/economicreport
EXECUTIVE SUMMARY

Today U.S. economic output is on par with the entire European Union composed of 35 nations, and greater than the next two countries, China and Japan, combined. Continued economic growth requires cost-effective transportation of goods, construction of infrastructure and extraction of resources using powerful, efficient, inexpensive motive power.

Diesel is the prime fuel for transporting freight, powering tractors, building roads, and meeting critically important demand for emergency services and national defense. More than four-fifths of products exported from and imported to the U.S. – by truck, train, ship or intermodal means – are moved using diesel technology. Three-quarters of the fossil-fueled equipment used in construction, mining and agriculture are diesel-powered. Diesel engines are the primary motive force for land and sea-route mass transit. Many emergency vehicles, such as fire and rescue vehicles, have diesel engines. Hospitals, government offices and businesses often rely on fast-response times and full load-carrying capability of diesel generators for emergency standby power. Our national defense relies on diesel to move material, munitions and weapons, both between theatres and on the battlefield. In short, diesel’s contribution to factories, farms and families is ubiquitous.

The advantages of diesel are manifest, making it a prime choice for these applications. Diesel power is energy-efficient, has high weight and energy power output ratios, has famously reliable and durable engines which can use renewable fuels, is highly portable and compact, and is safer compared to alternatives.

The synergistic relationship between the nation’s economic well-being and use of diesel technology can be seen even more clearly by examining the linkage between prosperity and diesel-reliant activity such as freight movement. For example, fuel use in trucks is highly correlated with GDP growth, moving together 98.5 percent of the time.

The Ceridian-UCLA Pulse of Commerce Index™ builds on the economic relationships of freight movement and diesel fuel use to track and forecast U.S. economic activity on a nearly real-time basis.

This study measures the shares of U.S. national income and employment that are tied to the use of diesel power using generally accepted economic methods and data. For this study’s purposes the scope of diesel technology is defined as (1) production and delivery of fuel; and (2) manufacturing and servicing of engines and equipment using those engines, such as trucks, tractors and pumps. In addition, the importance to the nation of several key industries – freight transportation, construction, agriculture, mining, transit, public safety and national defense – that rely largely on diesel technology to deliver their services is examined.
The diesel technology producing and servicing sectors directly contributed $183 billion and 1.25 million jobs to the U.S. economy in 2009. Another $300 billion was created through indirect and induced ripple effects. These diesel-related jobs are highly productive. Each employee in these industries created $146,000 directly in national income, nearly a third higher the national average of $110,000 per employee. The technology producing sectors were even higher, averaging $207,000 per job. This translates into higher wages for employees in those industries. In 2009, while the national average weekly wage for all workers was $876, the national average for the diesel technology and fuels sector was 60 percent higher at $1,398.

Beyond producing engines and fuel, diesel technology and fuel powered $455 billion or 3.2 percent of the 2009 GDP from key diesel-reliant industries. For every dollar of economic value from diesel technology, $4.51 is added elsewhere to national income in related industries that rely on diesel. The total GDP contribution for key diesel sectors, both technology producing and reliant, as well as diesel services, was $638.5 billion in 2009.

The new generation of clean diesel technology, ultra-low sulfur diesel fuel, cleaner engines and advanced emissions control technology, provides both environmental and economic benefits to the U.S. As policymakers look to promote cleaner, more fuel efficient technologies, its use will grow along with other competitive alternatives. Diesel technology's future value is further enhanced by its suitability for hybrid applications and its readiness to utilize a diverse range of first and second generation renewable and biodiesel fuels.

National fuel economy standards for cars and light-duty trucks beginning in 2017 are expected to be met in part by an increasing number of clean diesel passenger vehicle choices. Similarly, first-ever fuel efficiency standards for medium- and heavy-duty commercial trucks and buses beginning in 2014 will drive further innovation and efficiency gains in diesel technology as a key compliance strategy. For the fleet of existing vehicles and equipment, expanded use of new retrofit technologies, repowering and upgrading existing engines and expanded use of lower carbon biofuels are providing green jobs as well as cleaner air.

As policymakers look to further reduce petroleum consumption and greenhouse gas emissions, clean diesel technology has, and will continue to be a key solution.
INTRODUCTION:
HOW AND WHY DIESEL TECHNOLOGY IS USED

Over the last century, innovation by U.S. science and businesses have led to an increase in national productivity and output that has spread across the world. The United States of America remains the world’s economic engine even in current difficult times despite China and India’s rapid growth. Today U.S. economic output is on par with the entire European Union composed of 35 nations, and greater than the next two countries, China and Japan, combined.1

Efficient transportation fuels economic growth and requires powerful, cost-effective, inexpensive motive power. Diesel is the prime fuel for transporting freight, powering tractors, building roads and meeting critically important demand for emergency services:

- The vast majority of products exported from and imported to the U.S., by truck, train, ship or intermodal means, are moved using diesel technology. Most commercial trucks, including those used by independent trucking companies and “fleets” (e.g., store- and distributor-owned trucks) rely on diesel-powered engines. Air freight is dependent on diesel lifts, tugs and tractors to load cargo and move planes into position.

- A majority of off-road equipment, including tractors and stationary engines and pumps, depend on diesel. Three-quarters of the fossil-fueled equipment used in construction, mining and agriculture are diesel-powered. Diesel is the primary technology for pumping water for drainage and irrigation, and to generate remote power.

- Diesel engines are the primary power source for land- and sea-based mass transit. Buses, commuter trains and ferries rely predominantly on diesel technology.

- Diesel technology is critically important in protecting public safety and ensuring energy reliability. Virtually all emergency vehicles, such as ambulances, fire engines and tow trucks use diesel engines. Hospitals, data centers, air traffic control towers, pipelines and other critical service sectors often rely on diesel generators for emergency standby power in case the power grid suffers an outage.

- Our national defense relies on diesel to move material, munitions and weapons, both between theatres and on the battlefield.

Diesel’s contribution to factories, farms and families is ubiquitous. Thanks to technology which has and will continue to reduce emissions and improve efficiency, diesel power will continue to be the critical fuel for the nation’s economy for the years to come.

DIESEL’S ADVANTAGES

Diesel technology is the engine of choice for a variety of reasons:

- **Energy-Efficiency** – Compression-ignition diesel engines are typically 25 to 40 percent more efficient than those fueled by gasoline or natural gas-fueled spark-ignition engines in the same applications. A portion of this difference comes from diesel’s higher energy content over gasoline; but the majority stems from the greater inherent efficiency in diesel’s compression ignition. These fuel savings translate into lower costs for businesses and farms, which are passed on to consumers.

- **Power Output** – On a unit of work basis, diesel engines perform more work using less fuel than any other internal combustion engine. Diesel is essentially the only effective option for many heavy-duty engine applications. Diesel engines achieve higher power output at lower engine speeds than spark-ignition (e.g., gasoline or natural gas) engines, which makes them preferable for overcoming the inertia of large loads, and for excavating and moving earth and other heavy materials. In addition, only compression-ignition engines can achieve the high horsepower needed to power large equipment, such as locomotives. Diesel engines in excess of 10,000 horsepower are commonly used in ships and mining equipment.
• **Durability and Reliability** – Diesel compression-ignition engines require less maintenance, suffer fewer breakdowns and have longer service lives than spark-ignition engines. Diesel cars are famous for their longevity. Diesel trucks often travel hundreds of thousands of miles before their engines are overhauled, and then dispatched for hundreds of thousands more miles. Many ships rely on a single diesel engine to cross the oceans.

• **Portability** – For optimum performance, motive power sources use energy-dense fuel transportable to virtually any location where work is required. Diesel is among the most portable technology platforms. First, its energy density to weight ratio, including storage, is excellent. This allows vehicles to carry larger loads and go longer distances. Second, it is liquid at ambient temperatures so that it does not require any special storage or handling like natural gas which must be compressed or refrigerated,\(^a\) or electricity that requires heavy batteries or a fixed, stationary connection.\(^b\) Finally, diesel can easily power an electric motor either in a vehicle or in a remote location. Locomotives are a prime example of the linking of diesel with electricity to gain the benefits of both technologies.

• **Fuel Characteristics** – Diesel fuel has a higher flashpoint and lower auto-ignition temperature making the fuel less volatile, particularly if spilled.

• **Fuel Flexibility** – Diesel engines were originally invented to run on vegetable oils. Today, most diesel engines can run on high-quality blends of biodiesel with little modification as well as next-generation, drop-in renewable diesel fuels which offer even further benefits. This flexibility of the diesel platform can accelerate the introduction of these renewable diesel fuels across the economy.

**THE APPROACH OF THIS REPORT**

This study measures the share of U.S. national income and employment that is tied to the use of diesel in some manner using generally accepted economic methods and data. For this study’s purposes the scope of diesel technology is defined as (1) production and delivery of fuel; and (2) manufacturing of engines and equipment using those engines, such as trucks, tractors and pumps. In addition, the importance to the nation of several key industries – freight transportation, construction, agriculture, mining, transit, public safety and national defense – that rely largely on diesel technology to deliver their services is examined.

The report is organized into five main components. The Executive Summary provides an overview of diesel’s contribution to the U.S. economy. This is followed by Appendices A and B, which provide a more detailed look at the direct economic contribution of diesel industry (manufacturing, fuels and servicing industries which produce and deliver vehicles and equipment for use in the economy) and the economic activity that is catalyzed by the use of diesel technology by sector and subsector – agriculture, mining and resource extraction, construction, freight hauling, power generation, mass and personal transportation, national defense, and government fleets including public safety. In Appendix C, policies affecting the use of diesel and programs which support diesel technology development, use and promotion are discussed. Finally, there is a more detailed discussion of the report’s underlying methodology in Appendix D.

The appendices contain more detailed discussions of the analysis of each sector and the methodology used. Reference source material is listed in the appendices.

\(^a\) Liquid natural gas (LNG) locomotives require a separate fuel tender car.

\(^b\) A primary alternative to diesel, electricity, has some significant weaknesses that reduce its widespread applicability. Electric motors exhibit many of diesel’s characteristics, including power output, durability and reliability. But, electricity requires an external power source; either electric service must be delivered over wires, which limits the motive source’s mobility, or the power source must be added to the motor, which adds weight and cost. Electricity can be used for stationary uses, but the cost of installing an electricity connection can be cost prohibitive for temporary uses. In some applications solar arrays are a viable alternative, but their use is constrained by reliability – their ability to generate power is intermittent – and the need for sufficient space. Using electricity for rail poses significant safety problems that add to costs as well.
HOW IS ECONOMIC ACTIVITY ENGENDERED AND CATALYZED BY DIESEL TECHNOLOGY MEASURED?

Diesel technology (engines, fuels, equipment) supports a wide array of economic activities. Producing the inputs to diesel technology also contributes to the economy. Oil extraction, fuel refining, engine and vehicle manufacturing, and equipment servicing all require labor and capital. This fuel and equipment is used in trucks, trains and ships which facilitate the movement of goods and people and generate economic value through the productive work of equipment such as tractors, generators and portable machinery generating economic output in the agriculture, construction and mining sectors. All of these activities can be translated into expenditures of dollars and jobs created. **Figure 1** shows how this cycle of technology demand, production, use and output powers key parts of the U.S. economy.

*Figure 1: The Cycle of Economic Activity Related to Diesel Technology*

Economic activity is measured with two important concepts. The first is total output, the total expenditures and receipts associated with all transactions in the economy. Total output includes activities which may only reflect a physical transfer, with little associated added economic production, as well as the actual economic activity that is facilitated by or facilitates the transfer. For example, in diesel fuel production the crude oil input, which might come from Saudi Arabia, embodies most of the value in a gallon of fuel, but the refiner located in the U.S. processes the crude so that it can be used in a diesel engine. Thus the refiner’s total output includes both the price he paid for the gallon of fuel, and the value he added through the refining process to make it a usable fuel.

The second concept, value added, measures the specific economic activity associated with enhancing the product that has been transferred and is the component of total output that adds wealth to the economy. Value added reflects the economic value added to a product by an industry beyond the costs of purchasing the necessary inputs from other industries, as measured by labor and property income and indirect taxes. Each step of the production, delivery, and service process adds incremental value. The oil producer adds value by extracting the crude, the refiner adds value by processing it into diesel, and the retailer adds value by storing and selling the fuel to the final consumer. The cumulative value added across these industries, plus any out of state imports, equals the total cost to provide the final product to the end consumer. The sum of all of this value added for the U.S. is known as the Gross Domestic Product or GDP. The GDP excludes imports and excludes the multiplier effect from recirculating spending through the economy. The GDP growth rate is followed closely by economists and the media.

---

*1* How economic activity is measured for this study is described in more detail in Appendix D.

*2* Multipliers translates initial changes in an industry’s output or final demand for its products into values reflecting the recirculation of income and spending through the economy. This can amount to two to three dollars for every dollar of direct spending.
DESCRIBING DIESEL’S ROLE IN THE U.S. ECONOMY

The U.S. economy generated more than $24.8 trillion in total output in 2009, of which $14.1 trillion was value-added production,\(^2\) the latter being the measure of the GDP.\(^3\) This represents 25 percent of the world’s GDP. **Figure 2** shows the shares of GDP for each major industry sector in the U.S. in 2009.\(^4\) The diesel producing and reliant sectors are shown in bold. These constitute nearly half of the U.S. GDP. Even those sectors which are not highlighted still rely on diesel power to some extent such as, for example, providing for emergency backup electrical power at hospitals.

**Figure 2:** 2009 U.S. Gross Domestic Product by Sector {\$14.1 Trillion}
MAKING DIESEL TECHNOLOGY AND FUELS CONTRIBUTES DIRECTLY TO THE ECONOMY

The diesel industry is made up of several smaller components including engine and equipment manufacturing, fuel production and servicing and sales. These smaller components are actually subsectors of various U.S. industries ranging from 15 percent of the oil and gas sector to over 80 percent of the engine, truck trailer, rail and military equipment industries. Figure 3 shows the value added from the segment of the diesel manufacturing and fuel production industries that produce diesel goods, including the multiplier effect, indirect and induced economic activity, in associated economic sectors.6

The diesel-focused segments of these industries generated $101 billion directly, and $275 billion total including indirect and induced activity, or about 1.9 percent of U.S. GDP.7 This is about the same size as the utilities sector at $269 billion.5

Figure 3: Value Added by Diesel Technology Industries (2009) Billions $

Moreover, these industries accounted for 486,000 highly productive jobs. Each employee in these industries created $207,000 directly in national income, nearly double the national average of $110,000 per employee. This translates into higher wages for those employed in those industries. In 2009, while the average national weekly wage for all workers was $876, the national average for the diesel technology and fuels sector was 60 percent higher — $1,398 per week.

Diesel engine and equipment manufacturing, fuel refining and service sectors accounts for over 1.2 million jobs. (2009)

95 percent of heavy-duty truck equipment used in the U.S. is manufactured domestically.

---

6 The multiplier effect measures how much additional economic activity is generated by a direct expenditure on a specific activity. See Appendix D for a more detailed discussion.

7 By comparison, the Diesel Technology Forum’s report, Diesel Technology and the American Economy estimated that these sectors contributed $85 billion to the U.S. economy in 2000.
In addition to the industries in Figure 3, the diesel services sector, which is often embedded in other related industries for national income and accounting purposes added another $82 billion directly and $207 billion in total to the U.S. economy. These industries hired 764,000 individuals to support deployment, operations and maintenance of diesel vehicles and equipment.

It is important to note that, unlike so many other industries which have shrunk in recent years as companies moved their production overseas, the diesel industry largely remains “home grown”. With the exception of oil production and light-duty vehicles, most of these goods are being made in America. This means that the diesel industry is providing jobs for American citizens, adding value to the U.S. economy, and not contributing to the U.S. trade deficit.

The diesel industry makes additional important contributions to the economy through the high quality of jobs and the value of U.S. exports. All 50 states have some diesel industry employment in the case of equipment sales, repair and servicing. A preponderance of diesel manufacturing related jobs can be found in the Midwest, although recent manufacturing expansions have been announced over the last year in several other states including South Carolina, Texas and New York. The anticipated growth in light-duty diesel vehicles over the next several years may further bolster the industry’s contribution to the economy.

As the economy grows and the diesel passenger car market grows, so will the need for diesel fuel. The U.S. is self-sufficient in refining its fuel and even exports diesel fuel to other countries. Refineries accounted for the largest proportion of diesel-related exports, at $9.5 billion. Strong U.S. vehicle and equipment manufacturing has resulted in strong U.S. export figures from other diesel industry segments including truck manufacturing ($9.1 billion, or 36 percent of total production); construction equipment ($7.8 billion or 18 percent of production); and engine manufacturing ($6.9 billion of 22 percent of production). Altogether, diesel product and fuel exports represented $46.2 billion or 4.35 percent of U.S. exports in 2009, with an export-to-value ratio that was five times higher than the national average.

In summary, the direct contribution of the manufacturing and production of diesel engines, equipment, technology and fuels is substantial to the U.S. economy and to U.S. exports. However, the impact of diesel technology – as measured by its contributions to diesel-reliant industries, as discussed below is far more significant.
DIESEL TECHNOLOGY ENABLES AN EFFICIENT, EFFECTIVE U.S. ECONOMY

Beyond the diesel manufacturing and fuels sectors’ substantial contribution to the nation’s economy, diesel technology is used to create the goods and services Americans use in everyday life. This report focuses on a number of key industries that rely heavily on diesel, such as agriculture, mining and resource extraction, construction, freight hauling, passenger transport, and national defense. Figure 4 shows the value added of diesel technology acting as a catalyst to these industries’ output.

For every $1 of economic value from diesel technology, $4.51 is added elsewhere to national income of industries that rely on diesel.

For these sectors diesel technology facilitates $4.51 of value added to the broader economy for every dollar of added value from the diesel technology industries. In other words, for every dollar of economic value from diesel technology, $4.51 is added elsewhere to national income in related industries that rely on diesel. Diesel technology and fuel powered $455 billion or 3.2 percent of the 2009 GDP from key diesel-reliant industries. The total GDP contribution for key diesel sectors, both technology-producing and reliant, as well as diesel, was $638.5 billion in 2009.

Figure 4: Value Added by Diesel Contribution in Key Sectors (2009) Billions $

The synergistic relationship between the nation’s economic well-being and the use of diesel technology can be seen even more clearly by examining the linkage between fuel use, freight movement, and prosperity, as shown in two metrics. In one measure, fuel use in trucks is highly correlated with GDP growth, measuring 0.985; that is the two data sets move together 98.5 percent of the time. In contrast, electricity consumption has grown only 60 percent as fast as the U.S. economy from 1991 to 2010. Figure 5 shows economic growth and truck-related diesel consumption trends since 1970.

The Ceridian-UCLA Pulse of Commerce Index™ builds on these economic relationships of freight movement and diesel fuel use to track and forecast U.S. economic activity on a near real-time basis. Ceridian provides data on fuel purchase transactions from its electronic card payment services, and generates geographically-disaggregated trends on a daily basis.
Another measure is the U.S. Bureau of Transportation Statistics' (BTS) Transportation Services Index (BTS TSI). The TSI has two components, Freight and Passenger. The TSI’s Freight component, as discussed below, is dominated by diesel-powered modes, such as trucks, trains and ships, 82 percent of the national value and 84 percent of the tonnage is moved by diesel-powered vehicles. Figure 6 compares the Freight and Combined TSIs to a constant-dollar measure of the GDP since 1990. The correlation between the Freight TSI and the GDP is 0.90; that is, the two measures move together in 90 percent of the data. When the economy moves, freight moves, and diesel moves freight.

Figure 6: Comparison of Gross Domestic Product and BTS Transportation Service Index 1990-2010
Throughout history, people have depended on the earth’s resources for their survival. As civilization advances, men and women have developed these resources, resulting in greater efficiency and productivity. We have learned how to extract the earth’s minerals for our advancement, manage its land and waterways to feed ourselves and build structures to create hospitable communities. Today’s farming, mining and construction industries all require large, powerful equipment to literally move the earth. Diesel technology is the dominant motive force for these basic economic activities and to date there are few if any alternatives in these applications. High power output is a must; wear and tear is excessive in these environments; and remote locations require portability. Only diesel can deliver this combination. These industries rely heavily on diesel technology and as a result, diesel contributes directly to the value of their products.

In the agricultural sector, diesel catalyzes the greatest share of economic value, estimated at 35 percent, due in part to the fact that there is currently no cost-effective substitute for diesel in tractors and other farm equipment that can provide sufficient power to pull the necessary equipment weight at slow speeds while providing remote portability. In addition, diesel is used in more phases of crop “development” than in other industries. Diesel vehicles are used to plant the product, care for the product (through watering and applying fertilizers and pesticides), harvest the product and even bring the product to market for processing.

As U.S. farms have increased in size, they have also become more mechanized and productive, shifting in the process from gasoline-powered machinery to more efficient and powerful diesel-powered equipment. In 2009, agriculture produced $330 billion in output, of which $27.2 billion was for farm sales, contributing $176.6 billion to the nation’s GDP. Total added value of agriculture to the U.S. economy is estimated to be $365 billion. Farms employed 2.1 million in 2008.

In the case of extractive industries, over 60 percent of mining and fuel production equipment is diesel-powered. The nation gets 93 percent of its energy from mined sources, such as petroleum, natural gas, coal and uranium. Extracting these resources requires equipment running under extreme stress, often in remote and inhospitable areas. Again, diesel offers the best, and sometimes only power source to productively access these resources. As a result, diesel is fundamental to the mining, fossil fuel production and logging industry, which employed 641,000 people in 2009. The industry mined $413.5 billion of product in 2007. The industry created $254 billion in value-added to the GDP in 2007, and $241 billion in 2009.

Finally, the construction industry is also heavily dependent on diesel technology, and provides links between the diesel industry and virtually all others since construction is a core activity that resonates throughout the rest of the economy. Every building, power plant, reservoir, pipeline, roadway, airport, factory and landfill must be constructed. All economic activity passes through or over a constructed structure.

Diesel is the dominant fuel source of the construction industry, powering 60 percent of equipment and using 98 percent of all energy.

As U.S. farms have increased in size, they have also become more mechanized and productive, shifting in the process from gasoline-powered machinery to more efficient and powerful diesel-powered equipment.

In 2009, agriculture produced $330 billion in output, of which $27.2 billion was for farm sales, contributing $176.6 billion to the nation’s GDP. Total added value of agriculture to the U.S. economy is estimated to be $365 billion. Farms employed 2.1 million in 2008.

Diesel is the dominant fuel source, powering 60 percent of construction equipment and using 98 percent of all energy. The industry purchased $76 billion in diesel technology-related goods and services in 2009. In 2007, the nation’s construction industry employed 7.6 million people with a payroll of $336 billion. Even in the wake of the recent recession in 2010, 5.5 million workers held construction jobs (down from 7.6 million in 2007). Industry spending totaled $1.17 trillion, creating $657 billion in value-added to the GDP that year.
Diesel-powered trucks, trains, ships and intermodal systems moved 83 percent of freight by value ($11.7 trillion) and 85 percent by weight (12.5 billion tons) in 2007.

Diesel-powered trucks, trains, ships and intermodal systems moved 83 percent of freight by value ($11.7 trillion) and 85 percent by weight (12.5 billion tons) in 2007. The U.S. freight hauling and warehousing industry consists of more than 219,000 companies that employed nearly 4.5 million individuals with a payroll of $173.2 billion in 2007. These transportation sectors spend $46 billion on diesel technology inputs, 7.2 percent of their total revenues.

As the U.S. economy grows, freight movement increases across all modes of transportation, however trucking is the dominant mode of freight transportation in the U.S., moving 70 percent of all goods by weight and 71.3 percent by value. The vast majority of commercial trucks, including those used by for-hire independent trucking companies and private fleets rely on diesel-powered engines. In addition to its central role moving the U.S. economy, the trucking sector itself contributes substantially to the nation’s prosperity through spending and employment. Approximately 118,507 family- and corporate-owned trucking businesses operated in the U.S. in 2007, directly employing 1,480,000 Americans. The transportation and warehouse sector was responsible for $390 billion of the nation’s total gross product in 2009. The trucking industry supports an annual payroll of $57 billion dollars.

Railroads provide the second largest portion of freight movement, accounting for approximately 37 percent of the total ton-miles carried by various transportation modes (e.g., trucks, ships, pipelines and aircraft). Locomotives play an important role in reducing highway congestion by shifting traffic away from trucks and providing shippers with a cost-effective way of transporting their goods. Virtually all locomotives hauling freight in the U.S. are powered with diesel technology and are most efficient for transporting commodities and containers, particularly those moving to a fixed location for further processing. Nevertheless, even as rail transport continues to grow, trucking will remain critically important to the goods movement industry due to the challenges of citing new rail lines and the fact that more than 80 percent of towns are serviced only by truck. The nation’s 565 freight railroads employs 183,700 individuals and pays wages and benefits averaging $98,500 per employee. The industry delivered $30.8 billion in value added or national income in 2009.

About 78 percent of the ships that haul freight are diesel-powered and like the railroads, are primarily used for transporting containers of manufactured goods or commodities such as oil, ore, wheat or other goods. Marine vessels have some of the biggest diesel engines in the world, enabling global trade and providing an example of the reliance of virtually all export industries on diesel technology. The water transportation industry employed 66,800 in 2008, with a payroll of $4.47 billion in 2009. Economic value added was $14.3 billion in 2009.
Diesel enables the efficient moving of people by rail, bus and cars

Like most developed countries, passenger cars and trucks account for the largest share of total passenger miles, however diesel moves more large groups of people on the ground and over water than any other motive power. Diesel is fuel efficient and can move a large passenger load with ease. Reliability is key for passenger service and durability lowers operating costs. Fuel portability is particularly important for intercity travel around most of the country. Approximately 71 percent of transit buses and 58 percent of commuter rail passenger-miles are provided by diesel-fueled trains. The transit and local and interurban personal transportation industry employs 416,000 people, with a payroll of $10.5 billion in 2009. About three-quarters of these individuals are employed by private firms providing ground passenger and school bus transport; the other quarter is employed by local government transit agencies. The industry delivered an economic value added of $41 billion in 2008.

Passenger cars are the dominant mode of transportation in the U.S.; however only 3.4 percent of the cars are presently diesel-powered. Diesel accounts for a larger share of pickup trucks (13.6 percent) due to its superior power and performance for hauling trailers for recreational and commercial purposes.

In recent years, the number of available diesel vehicles has been growing and manufacturers offering these vehicles are being rewarded with strong interest among consumers. In the first eight months of 2011 (Jan. 1-Aug. 31) clean diesel automobile sales in the United States increased by an impressive 37.0 percent compared to the same period in 2010 while the overall automobile market experienced a 10.4 percent increase. Some analysts predict that diesel passenger cars will account for 10 percent of the market by 2015. With diesels offering 20 to 40 percent greater efficiency over their gasoline counterparts, a growing share of diesel passenger vehicles can help reduce petroleum consumption and GHG emissions.

Diesel is a prime source of industrial site, remote and back-up power generation

Diesel generators’ high reliability, response capabilities, fuel characteristics and relatively low cost make them the technology of choice to supply back-up power in large buildings, shopping malls, hospitals, universities, communications and data centers, waste water treatment facilities, and factories, among other locations. Diesel engines also are relatively portable and are readily adaptable for remote operations.

Dispersed generation, 93 percent of which are internal combustion engines (ICE), is typically remotely located from the utility grid. For most of these applications, the generator is the sole power source and the ICE’s reliability and durability is critical. These engines are still the primary source of power for remote Alaskan villages that are beyond the reach of the electricity grid.

The U.S. EPA estimates that 1.15 million engines were in stationary use in 2008. About 26,500 megawatts (MW) of dispersed and distributed generation is located at commercial and industrial premises. Of this, 14,000 MW, 1.3 percent of total U.S. generation capacity, consists of ICEs, often compression ignition.
Governments are major vehicle fleet operators, with the federal government operating the largest fleet in the world, numbering about half a million vehicles in 2009 (excluding military vehicles). This fleet includes a mix of on- and off-road vehicles and equipment including highway service and vocational vehicles, construction machines, transit buses, land maintenance-related vehicles (e.g., tractors), and fire and rescue equipment. It also owns industrial back-up diesel generators for public works projects. As one component of this fleet, the federal government maintains about 120,000 diesel trucks.

The U.S. government accounts for two percent of energy use in the United States. The Department of Defense accounts for 80 percent of this total, with the Navy accounting for one-third of that 80 percent. In the 1990s, DOD transformed its land-based fleet to run on diesel. Diesel fuel No. 2 (DF-2) and Jet Propellant 8 (JP-8) – a kerosene-based propellant used to operate off-road vehicles, tanks, jets and even field stoves – are the two most common fuels used in the military.

Commitments to use more renewable fuels within the military are strong. The Army is seeking to use 25 percent renewable energy by 2025 while the Navy is hoping to use renewable fuels for 50 percent of its energy needs by 2020. The Air Force is also planning to fly on a 50-50 blend of renewable and conventional fuels by 2016. Based on current estimates, achievement of the Navy and Air Force goals would result in the purchase of over 700 million gallons of renewable fuels each year.

The U.S. military relies heavily on off-road diesel engines for its training and overseas activities. Diesel technology provides the power, durability and reliability that the military needs in many applications. Fuel flexibility also is important in the context of a world-wide fighting force. A Defense Department study conducted found 360,000 diesel engines used more than 83 percent of the fuel powering U.S. Army and Marine Corps vehicles and generators, with the remainder going to the Abrams battle tank, which is powered by a gas turbine. The Navy has another 700 diesel engines in its fleet of 285 vessels.

In addition to the federal government, state and local government fleets managed approximately 3.8 million vehicles, plus a quarter million trailers in 2009. Of these, 485,000 were buses and 1.9 million were trucks, ranging from light-duty to tractor-trailers to emergency response.
EXISTING AND EMERGING PUBLIC POLICIES INDICATE A STRONG FUTURE ROLE FOR DIESEL TECHNOLOGY

Public policies adopted at the state and federal levels will significantly shape the competitive nature of different fuel technologies. Over the past decade, laws and regulations have been adopted which require lower emissions and greater efficiencies from vehicles and stationary sources. Regulatory pressure is now shifting to greenhouse gas emissions, most prominently as embodied in California’s Assembly Bill 32 (the Global Warming Solutions Act). Key federal policies include higher fuel economy standards for both light- and heavy-duty vehicles, and increased requirements of biomass-based diesel in the Renewable Fuels Standard (RFS2). The growing requirement for advanced biofuels under the RFS2 regulation is supporting the development of next-generation, “drop-in” renewable diesel fuels, with commercial-scale production of these fuels forecast to grow significantly in the next few years. Federal emission standards also are being tightened for off-road, marine and stationary engines. These policies, combined with higher gasoline prices, are fostering a more diverse set of fuels being used for transportation, construction, cultivation and electricity generation.

The federal government funds various research and development efforts, including those under the Department of Energy’s Vehicle Technologies and Biomass Programs. A study by the U.S. Department of Energy found public R&D investment returned large benefits. “The federal return on investment is greater than 60 to 1 ($7.7 billion in fuel savings from $125 million in research funding) for technologies developed from federal research between 1999 and 2007 (benefits were calculated for model years 2004 to 2008).” This report projected that federal research efforts can save as much as 4.5 billion barrels of oil.

One other area where public policies have influenced the diesel industry is its support for voluntary diesel retrofit programs. EPA’s regulatory programs have required significantly reduced emissions from on- and off-road diesels, however there is strong interest in retrofitting or upgrading existing (legacy) vehicles as a means of reducing emissions and improving air quality.

According to the Manufacturers of Emission Controls Association (MECA), 24,640 diesel exhaust control devices were sold for retrofit applications in 2010, a figure which has been relatively consistent over the last several years.11 Many of these have been funded in part with federal or state funds to offset the cost of this investment which does not provide an economic payback to the vehicle or equipment owner. This figure does not account for the value of other retrofit options that may not use an exhaust control device on existing equipment such as engine rebuilds, repowers or even total vehicle replacements. These projects have actually accounted for a majority of projects funded under the U.S. Environmental Protection Agency’s Diesel Emissions Reduction Program (known as DERA for the Act under which it was passed), as well as similar diesel retrofit projects funded by other government programs such as the Department of Transportation’s Congestion Mitigation and Air Quality Program and the Department of Agriculture’s Environmental Quality Incentives Program.
SUMMING UP: POWERING THE AMERICAN ECONOMY

Simply put, diesel technology is ubiquitous throughout the U.S. economy. Because of its power, efficiency and portability, reaching even remote locations, diesel probably touches even more aspects of the American economy than grid-connected electricity. Almost every product is moved by diesel-powered vehicles; almost every structure is built with and uses materials harvested or excavated by diesel equipment. We would not have the abundance of foods that we now take for granted without diesel technology. The national wealth creation enabled by the use of diesel technology is manifest.

Diesel probably touches even more aspects of the American economy than grid-connected electricity.

Almost 1 in every 20 dollars of the GDP is contributed by diesel power.

Tables 1 and 2 summarize the economic contributions of diesel to the U.S. economy through those sectors that produce diesel technologies and fuels, and are most reliant on diesel. The data and analysis conducted on each of these sectors are described in greater detail in the appendices of this report.

The diesel-delivery super sector – technology, fuels and services – produced $517.4 billion in output, employed one and a quarter million people, and created $183 billion directly towards the national income in 2009 as listed in Table 1, and added another $300 billion in multiplier effects through the economy according to the IMPLAN analysis.

Table 1: Diesel Technology and Fuels Industry Statistics

<table>
<thead>
<tr>
<th>DIESEL INDUSTRY SUBSECTOR</th>
<th>TOTAL OUTPUT</th>
<th>VALUE ADDED</th>
<th>EMPLOYMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle, Equipment &amp; Engine Manufacturing</td>
<td>$178.2 billion</td>
<td>$45.7 billion</td>
<td>349,000</td>
</tr>
<tr>
<td>Oil Production &amp; Refining</td>
<td>$218.6 billion</td>
<td>$55.3 billion</td>
<td>137,000</td>
</tr>
<tr>
<td>Sales, Repair &amp; Servicing</td>
<td>$120.7 billion</td>
<td>$82.1 billion</td>
<td>764,000</td>
</tr>
<tr>
<td>Total</td>
<td>$517.5 billion</td>
<td>$183.1 billion</td>
<td>1,250,000</td>
</tr>
<tr>
<td>Multiplier Effect</td>
<td></td>
<td>$300.1 billion</td>
<td></td>
</tr>
<tr>
<td>Total Value Added</td>
<td></td>
<td>$483.1 billion</td>
<td></td>
</tr>
</tbody>
</table>

For the diesel-reliant sectors, diesel facilitated $455 billion in GDP, as delineated in Table 2. Agriculture is the most reliant on diesel, with 35 percent of production using the technology to grow crops, raise livestock, and ship products. Manufacturing has the largest absolute amount depending on diesel use at $161 billion based 10.5 percent of product tied to the technology.
In total, both diesel-delivery and diesel-reliant industries contributed a combined $638.5 billion in 2009 to the U.S. GDP or about 4.5 percent, almost one in every 20 dollars. And that does not account for the added downstream influences in consumption of retail commodities and energy. These sectors generated $1,169 billion in output.

**Table 2: Diesel Reliance and 2009 U.S. Gross Domestic Product**

<table>
<thead>
<tr>
<th>SECTORS</th>
<th>PERCENT DIESEL CONTRIBUTION OR INFLUENCE</th>
<th>DIESEL GDP SHARE ($ BILLIONS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>35.0 percent</td>
<td>$40.3</td>
</tr>
<tr>
<td>Coal Mining</td>
<td>26.8 percent</td>
<td>$4.4</td>
</tr>
<tr>
<td>Electric Power Utilities</td>
<td>24.6 percent</td>
<td>$47.0</td>
</tr>
<tr>
<td>Mineral Mining</td>
<td>17.0 percent</td>
<td>$4.9</td>
</tr>
<tr>
<td>Air Transport</td>
<td>16.8 percent</td>
<td>$9.5</td>
</tr>
<tr>
<td>Oil and Gas Production</td>
<td>15.9 percent</td>
<td>$25.1</td>
</tr>
<tr>
<td>Couriers and Messengers</td>
<td>15.2 percent</td>
<td>$8.5</td>
</tr>
<tr>
<td>Residential Construction</td>
<td>14.0 percent</td>
<td>$21.4</td>
</tr>
<tr>
<td>U.S. Postal Service</td>
<td>13.7 percent</td>
<td>$7.4</td>
</tr>
<tr>
<td>Government</td>
<td>13.3 percent</td>
<td>$15.1</td>
</tr>
<tr>
<td>Scenic and Sightseeing</td>
<td>12.4 percent</td>
<td>$5.2</td>
</tr>
<tr>
<td>Nonresidential Construction</td>
<td>11.7 percent</td>
<td>$49.3</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>10.5 percent</td>
<td>$161.4</td>
</tr>
<tr>
<td>Warehousing</td>
<td>8.8 percent</td>
<td>$3.6</td>
</tr>
<tr>
<td>Water and Sewage Utilities</td>
<td>7.0 percent</td>
<td>$0.5</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>6.8 percent</td>
<td>$51.9</td>
</tr>
<tr>
<td><strong>Total for Diesel-Reliant Sectors</strong></td>
<td></td>
<td><strong>$455</strong></td>
</tr>
</tbody>
</table>
REFERENCES


5 U.S. Census Bureau, 2011, 2011 Statistical Abstract of the United States, Table 669


APPENDIX A:

PROVISION OF DIESEL TECHNOLOGY: Selling Goods and Services to Diesel Users

The diesel vehicle, equipment, engine manufacturing and fuel producing industries accounted for $396.7 billion in output in 2009, and $101.0 billion in value added. Based on the multiplier effect, these industries induced another $174.3 billion in economic activity, for a total of $275.3 billion in value added. In comparison, the energy, communication and water utilities sector generated $269 billion.

Diesel technology includes the “hardware” components in the engines and associated equipment and the fuel that is burned in them. The engines, vehicles, generators and pumps compose the manufactured technology. The extraction and refining of petroleum account for the fuel portion.

Table 3 lists the industry sectors that directly manufacture and deliver diesel technology to businesses, utilities and services, which in turn rely on the technology to produce food, infrastructure and other goods; transport freight and people; generate power; or pump fluids. These industries span fuel production and processing; engine manufacturing; and production of trucks, buses, locomotives, ships, and construction and farming equipment. Table 3 also shows the proportion each sector’s output and the percentage attributed to diesel technology or fuel. For example, 15 percent of petroleum and gas production, measured by value, is refined into diesel fuel, as shown for sector 211, oil and natural gas production. For sector 32411, petroleum refining, 25 percent of refined product sales are diesel fuel. Of truck and bus manufacturing, sector 336120, 88 percent of production is diesel-powered vehicles based on vehicle population.

Table 3: Industries Producing Diesel Technology and Share of Industry Output in 2009

<table>
<thead>
<tr>
<th>NAICS Code</th>
<th>NAICS Industry Sector</th>
<th>Diesel Share of Output</th>
<th>Share of U.S. Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>211</td>
<td>Oil and gas extraction</td>
<td>15.3%</td>
<td>100%</td>
</tr>
<tr>
<td>213111</td>
<td>Drilling of oil and gas wells</td>
<td>15.3%</td>
<td>100%</td>
</tr>
<tr>
<td>213112</td>
<td>Support activities for oil and gas operations</td>
<td>15.3%</td>
<td>100%</td>
</tr>
<tr>
<td>32411</td>
<td>Petroleum refineries</td>
<td>23.0%</td>
<td>106%</td>
</tr>
<tr>
<td>33311</td>
<td>Farm machinery and equipment manufacturing</td>
<td>35.0%</td>
<td>106%</td>
</tr>
<tr>
<td>33312</td>
<td>Construction machinery manufacturing</td>
<td>30.0%</td>
<td>106%</td>
</tr>
<tr>
<td>33313</td>
<td>Mining and oil and gas field machinery manufacturing</td>
<td>30.0%</td>
<td>106%</td>
</tr>
<tr>
<td>33319</td>
<td>Other engine equipment manufacturing</td>
<td>30.0%</td>
<td>106%</td>
</tr>
<tr>
<td>333111</td>
<td>Pump and pumping equipment manufacturing</td>
<td>12.4%</td>
<td>98%</td>
</tr>
<tr>
<td>333225</td>
<td>Overhead Traveling Crane, Hoist, and Monorail System Manufacturing</td>
<td>12.4%</td>
<td>98%</td>
</tr>
<tr>
<td>333224</td>
<td>Industrial Truck, Tractor, Trailer, and Stacker Machinery Manufacturing</td>
<td>12.4%</td>
<td>98%</td>
</tr>
<tr>
<td>33331</td>
<td>Motor and generator manufacturing</td>
<td>26.4%</td>
<td>98%</td>
</tr>
<tr>
<td>333411</td>
<td>Automobile manufacturing</td>
<td>9.5%</td>
<td>98%</td>
</tr>
<tr>
<td>333412</td>
<td>Light truck and utility vehicle manufacturing</td>
<td>9.5%</td>
<td>98%</td>
</tr>
<tr>
<td>333413</td>
<td>Heavy-duty truck manufacturing</td>
<td>9.5%</td>
<td>98%</td>
</tr>
<tr>
<td>333414</td>
<td>Truck trailer manufacturing</td>
<td>100.0%</td>
<td>110%</td>
</tr>
<tr>
<td>333415</td>
<td>Motor home manufacturing</td>
<td>97.0%</td>
<td>110%</td>
</tr>
<tr>
<td>333416</td>
<td>Motor vehicle parts manufacturing</td>
<td>97.0%</td>
<td>110%</td>
</tr>
<tr>
<td>333417</td>
<td>Railroad rolling stock manufacturing</td>
<td>97.0%</td>
<td>110%</td>
</tr>
<tr>
<td>339991</td>
<td>Ship building and repairing</td>
<td>78.0%</td>
<td>98%</td>
</tr>
<tr>
<td>339992</td>
<td>Military armed vehicle, tank, and tank component manufacturing</td>
<td>84.4%</td>
<td>98%</td>
</tr>
<tr>
<td>42311</td>
<td>Motor Vehicle and Motor Vehicle Parts and Supplies Merchant Wholesalers</td>
<td>12.4%</td>
<td>100%</td>
</tr>
<tr>
<td>42341</td>
<td>Construction equipment merchant wholesalers</td>
<td>30.4%</td>
<td>110%</td>
</tr>
<tr>
<td>42342</td>
<td>Farm and garden equip. merchant wholesalers</td>
<td>30.4%</td>
<td>110%</td>
</tr>
<tr>
<td>42343</td>
<td>Industrial machinery merchant wholesalers</td>
<td>30.4%</td>
<td>110%</td>
</tr>
<tr>
<td>42344</td>
<td>Industrial machinery dealers</td>
<td>30.4%</td>
<td>110%</td>
</tr>
<tr>
<td>42345</td>
<td>Automotive dealers</td>
<td>30.4%</td>
<td>110%</td>
</tr>
<tr>
<td>44411</td>
<td>Recreational vehicle dealers</td>
<td>30.4%</td>
<td>110%</td>
</tr>
<tr>
<td>44412</td>
<td>Automotive parts and accessories stores</td>
<td>30.4%</td>
<td>110%</td>
</tr>
<tr>
<td>44413</td>
<td>Gasoline stations (including truck stops)</td>
<td>30.4%</td>
<td>110%</td>
</tr>
<tr>
<td>53212</td>
<td>Truck, trailer, and RV rental and leasing</td>
<td>49.0%</td>
<td>110%</td>
</tr>
<tr>
<td>53213</td>
<td>Transportation equipment rental and leasing</td>
<td>49.0%</td>
<td>110%</td>
</tr>
<tr>
<td>53214</td>
<td>Other heavy-duty rental and leasing</td>
<td>49.0%</td>
<td>110%</td>
</tr>
<tr>
<td>81111</td>
<td>Automotive mechanical and electrical repair</td>
<td>49.0%</td>
<td>110%</td>
</tr>
<tr>
<td>81112</td>
<td>Automotive body, interior, and glass repair</td>
<td>49.0%</td>
<td>110%</td>
</tr>
<tr>
<td>81113</td>
<td>Commercial machinery repair and maintenance</td>
<td>49.0%</td>
<td>110%</td>
</tr>
</tbody>
</table>

\[a\] The multiplier effect measures how much additional economic activity is generated by a direct expenditure on a specific activity. See Appendix D for a more detailed discussion.

\[b\] Each sector shows its North American Industry Classification System (NAICS) code number. NAICS code numbers are used by federal statistical agencies to classify and summarize information about similar businesses within an industry.
**Figure 7** shows the proportion of national consumption of these sectors’ output that is produced within the U.S. as compiled from the IMPLAN input-output model database. In other words, this is the percentage of total industry product that comes from businesses in the U.S. For example, 48 percent of the oil consumed by the U.S. comes from in-country wells; 95 percent of the heavy-duty truck equipment used in the U.S. is manufactured domestically. Where sectors show more than 100 percent of U.S. demand, those are creating net exports. For example, farm machinery has net exports equal to 29 percent of the sector’s output.

It is important to note that, unlike so many other industries which have shrunk in recent years as companies moved their production overseas, the diesel industry largely remains “home grown”. With the exception of oil production and light-duty vehicles, most of these goods are being made in America. This means that the diesel industry is providing jobs for American citizens, adding value to the U.S. economy, and not contributing to the U.S. trade deficit.

For example, apart from indirect impacts (i.e., spending fuel savings in the local economy), diesel technology manufacturing jobs tend to be concentrated in the four state Michigan-Illinois-Indiana-Ohio region. This region was home to 55 percent of engine and 85 percent of North American transmission production in 2008. Over time, this regional concentration may become less predominant as evidenced by recent announcements of growing diesel manufacturing activity in states outside the region including New York, South Carolina, Tennessee, and Texas.

**VEHICLE, EQUIPMENT AND ENGINE MANUFACTURING**

*The diesel vehicle, equipment and engine manufacturing industries accounted for $178.2 billion in output in 2009, and $45.7 billion in value added. Based on the multiplier effect, these industries induced another $88.5 billion in economic activity, for a total of $134.3 billion in value added.*

Unfortunately the diesel industry, like many others, has suffered from the vagaries of the U.S. economy, maybe most keenly seen with the ebb and flow of heavy-duty truck sales. Almost 90 percent of these trucks are diesel-powered and while the industry hit a peak of 694,000 vehicles being produced in 2006, this number shrank by more than half to 312,000 units in 2009. More recently sales have rebounded strongly, increasing 143 percent in the first half of 2011 over the same period in 2010. 

**Figure 8** shows how heavy-duty truck sales have ebbed and flowed with the U.S. and world economies.

---

*In 2009, while the national average weekly wage was $876, the national average for the diesel technology and fuels sector was 60 percent higher - $1,398.*
As expected, this growth in sales has led to a commensurate increase in heavy-duty truck registrations, almost all powered by diesel engines. Single-unit and combination trucks registrations reached 10 million in 2008, growing more than 50 percent over the last 30 years. The combination trucks in particular are dominated by heavy-duty tractor-trailers that are almost entirely diesel-powered.

In Figure 9 these truck manufacturing jobs are added to other industry segments, showing that these diesel industries directly created almost a half-million jobs in 2009. Fuel production required 137,000 employees, while technology manufacturing employed another 349,000. This was even after the “Great Recession” of 2008 greatly impacted the construction and vehicle manufacturing sectors.

These jobs are highly productive. Each employee in these industries created $207,000 directly in national income, nearly double the national average of $110,000 per employee. This translates into higher wages for those employed in those industries shown in Figure 10. In 2009, while the national average weekly wage was $876, the national average for the diesel technology and fuels sector was 60 percent higher - $1,398.
LIGHT-DUTY VEHICLES: AN EMERGING U.S. MARKET

Light-duty diesel vehicles and heavy-duty pickup trucks have been offered in the U.S. by several manufacturers in varying numbers of models since the oil embargo of the 1970’s but still have just a 3.4 percent share of national new vehicle sales,\(^4\) and less than half a percent of fuel sales due to relatively low gasoline prices and lingering worries about vehicle performance and emissions, embedded in memories of two-decades old technology.\(^5\) The diesel passenger vehicle market has been largely dominated by heavy-duty pickup trucks (diesel powers 13.6 percent of pickups\(^6\)) due to diesel’s superior power and performance – enabling towing of trailers for recreational and commercial purposes. Recent advances in emission control technology, coupled with the introduction of ultra-low sulfur diesel fuel in 2006 enabled diesel-powered cars and light-duty trucks to be certified for sale in all 50 states, generating greater interest in this new generation of clean diesel cars and SUVs.\(^7\) Ongoing policy changes and technology advances suggest that diesel could modestly increase its market share over the next decade. According to a report by UBS Investment Research,

“The new generation of clean diesel cars has permanently dispelled the image of ‘loud, rough, hard to start, and smoky’ due to issues with not fully optimized technology put on the market decades ago. The present-day reality (as seen in the European fleet, where diesels make up almost five out of 10 new cars) is that constant refinement and development has eliminated all of these problems.”\(^7\)

These changes, combined with higher gasoline prices, and market success of a limited range of existing diesel products have prompted vehicle manufacturers – notably Audi, GM, BMW, Daimler, Mazda, and Volkswagen – to consider diesel as a new option for light-duty passenger applications or expand the number of diesel offerings available. Market success of the new generation of diesels has met or exceeded expectations for all manufacturers. For example, Volkswagen is selling up to 85 percent of its Jetta SportsWagen models as diesels, and by 2014 up to 20 percent of BMW’s fleet will be diesels.\(^8\) This success is leading the way for other manufacturers to add diesels to their offerings, as most recently evidenced by General Motors’ recent announcement that it would offer a diesel version of the Chevy Cruze in 2013.

\(^4\) For example, although the diesel-fueled Fiesta subcompact, which gets 65 miles per gallon, is available in Europe, Ford doubts that enough American buyers would purchase the vehicle to make the cost of obtaining emissions certification worthwhile.
Recent trends bolster expectations that, at minimum, there will be steady growth in demand for light-duty diesels. In the first eight months of 2011 (January 1-August 31) clean diesel automobile sales in the United States increased by an impressive 37 percent compared to the same period in 2010 while the overall automobile market experienced a 10.4 percent increase.9 By 2015, as many as 10 percent of new cars and trucks sold in the U.S. could have diesel engines.10 The EIA forecasts in its 2010 Annual Energy Outlook that light-duty diesel sales could reach 1.05 million vehicles by 2035, shown in Figure 11. Increased adoption of diesel technologies, particularly in the light-duty vehicle market, would induce additional employment. For example, switching from six- and four-cylinder gasoline engines to four-cylinder diesel engines, with after-treatment systems, could create almost 18,000 additional jobs nationwide according to CALSTART.11 Development of the biofuels industry could induce a similar number of new employment opportunities.12

In Europe advanced diesel technology represents almost 50 percent of Europe’s light-duty vehicle market due to favorable tax policies where diesel is taxed at significantly lower rates than gasoline, and stricter greenhouse gas tailpipe emission standards.4 In contrast, in the U.S. diesel is taxed at six cents per gallon more (federal fuel tax) than gasoline. Nationwide, diesel fuel taxes (federal, state and local combined) averaged 54 cents per gallon compared to 48.9 for gasoline.13 GHG standards are only about to become binding on manufacturers. Higher fuel prices in general are now pushing the public toward more fuel-efficient vehicles, which is likely to be favorable to diesel.

Figure 11: Projected Light-Duty Diesel Vehicle Sales to 2035, 2010 Annual Energy Outlook

Diesel engines are more expensive than gasoline technology due to the need for additional exhaust processing, particularly related to NOx, which can increase cost by up to $4,000, but provide up to 40 percent better fuel efficiency.14 On the other hand, diesel engines are less costly than hybrids, provide better performance, and are competitively fuel-efficient.15 When taking capital and fuel costs, pollutant and greenhouse gas emissions, as well as performance into account, diesel is the most promising alternative to existing petroleum engines.16

This diesel advantage was confirmed in a 2010 Carnegie Mellon study.17 In looking at the total cost of ownership, researchers found that while fuel economy explained a portion of the premium in resale price of diesel over gasoline versions of the same model, other factors, including overall performance and prestige contrib-

---

**DIESEL HYBRIDS IN THE FUTURE?**

Adding hybrid technology to already fuel-efficient diesel engines is a future potential vehicle choice as witnessed in concept car format. It combines the fuel efficiency of diesel over gasoline, the performance premium of a diesel generator’s ability to accelerate an electric motor, and the efficiency gains of using electricity seen in gasoline hybrids such as the Toyota Prius. Diesel hybrids have large potential fuel economy gains, but vehicle cost could also be high. As a result, market potential for these technologies is highly dependent primarily on crude oil prices and government regulations. Hybrid technology is already successfully deployed with urban transit buses and medium-size commercial trucks.

---

"Gasoline-electric hybrids such as the Toyota Prius are little more than novelties in Berlin and elsewhere, despite well-documented Green sensibilities in Germany," Jeremy Cato, “European Buyers Can Choose from a Wide Range of Small, Affordable Cars with Great Fuel Economy and Loads of Features, but we’ll be lucky to see them in North America,” The Globe and Mail, September 9, 2010.
uted to this price premium. In other words, diesel cars and trucks delivered added attributes beyond fuel savings that increased their value.

**FUEL PRODUCERS, REFINERS AND SALES**

**OIL PRODUCTION AND REFINING**

The U.S. consumed 1.54 billion barrels of diesel fuel in 2010 – 23 percent of total petroleum use. The diesel fuel production and refining industry accounted for $218.6 billion in output in 2009, creating $55.3 billion directly in value added to the GDP. The induced economic impacts through the multiplier effect amounts to $85.6 billion in value added for a total of $141.0 billion.

The U.S. is the third largest oil producing country in the world, after Russia and Saudi Arabia. Domestic oil production still supplies more than a quarter of the country’s petroleum demands, despite a 25 percent drop in domestic production over the last 20 years. While the nation imports most of its crude petroleum, most predominately from Canada, Saudi Arabia, and Mexico, the U.S. is largely self-sufficient in refining its fuel and even exports refined fuels to other countries, particularly Mexico. The refining industry shipped $770 billion in products in 2008 according to the Annual Survey of Manufacturers. A recent study conducted for the American Petroleum Institute estimated that the oil and gas industry generates $966 billion in value added and eight million jobs to the American economy. Based on the analysis prepared in this report, diesel fuel production and refining contributes about 16 percent of that amount.

**REFINING: VOLUMES, DOLLAR VALUES AND TRENDS**

Figure 12 shows the shares of petroleum output by final product. Diesel fuel accounts for the second largest share of output (23 percent), after motor gasoline (49 percent). From 2000 to 2010, annual U.S. petroleum consumption (including imports) averaged 7.31 billion barrels, 68 percent of which went to the transportation. And of this 68 percent, 56 percent was produced domestically.

The Energy Information Administration projects in its 2011 Annual Energy Outlook that demand for diesel will increase from 3.2 million barrels per day in 2009 to 4.5 million barrels per day or 41 percent by 2035, equaling an annual growth rate of 1.4 percent. In comparison, gasoline sales are expected to increase only 3.2 percent, at a 0.1 percent annual rate. Total transportation fuel demand is forecasted to increase 18.2 percent over the period.

**Figure 12: U.S. Refinery Output, 2010 (6.72 billion barrels)**

![Image of refinery output chart](Image186x42 to 534x260)
Figure 13 shows where diesel fuel was used in the transportation sector. Diesel is the dominant fuel in medium and heavy-duty trucks, rail and buses, exceeding 85 percent of the fuel used for those modes. Heavier residual fuel oil used in vessels also powers marine diesel engines, some of which reach 100,000 horsepower. In summary, waterborne vessels rely on diesel engines for more than 77 percent of their energy use.

**Figure 13: Domestic U.S. Transportation Energy Consumption (2008)**

![Graph showing transportation energy consumption by mode, with diesel fuel dominating in medium and heavy-duty trucks, rail, and buses.]

**RENEWABLE DIESEL FUELS: “GREEN” DIESEL**

While the steady growth in population and vehicle miles traveled provides a natural increase in demand for fuel, one way to offset this growing demand is through the greater use of renewable fuels. In 2007, Congress expanded the Renewable Fuel Standard Program originally passed in 2005, increasing the volume of renewable fuel required to be blended into transportation fuels from 9 billion gallons in 2008 to 36 billion gallons in 2022. Of this total, biomass-based diesel blended volumes must be at least 800 million gallons in 2011, growing to 1.28 billion gallons in 2013. In addition to this volumetric federal mandate, seven states have also passed biomass-based diesel mandates, while California has chosen to regulate the carbon content of the fuels through its Low Carbon Fuel Standard.

Biodiesel production peaked in 2008 at 691 million gallons through the combination of the federal production tax credit and high oil prices. A report for the National Biodiesel Board estimated that 21,000 jobs were created throughout the economy from biodiesel production in 2009. The industry spent $1.6 billion to produce 545 million gallons that year. Production fell to 315 million gallons in 2010 after the tax credit of $1 per gallon to fuel blenders lapsed.

Thanks to a reinstitution of the tax credit for 2011, the National Biodiesel Board estimates that it is on track for a record year in 2011, reaching 800 million gallons of biodiesel. Industry expenditures are projected to increase to $8 billion by 2015, adding $7.2 billion to the U.S. GDP and 74,000 jobs.

“While virtually all the renewable diesel fuel being produced in the United States today is biodiesel, next generation renewable diesel fuels, which offer additional economic and environmental benefits are quickly being developed. The Department of Energy’s Energy Efficiency and Renewable Energy Biomass Program is working with the private sector to further increase the availability of advanced biofuels to improve energy security, stimulate the economy and create green jobs. As of 2011, the Department of Energy had invested over $1 billion in a variety of integrated biorefinery projects, many of which are focused on producing next generation, renewable hydrocarbon fuels that could be used in diesel engines. These projects represent up to 170 million gallons in planned capacity of biofuels and production by 2014, with an industry cost share of approximately $2.5 billion. The United States Department of Agriculture is also working with the private sector to expand biofuel markets and commercialize new technologies.

According to the International Energy Agency, the biofuels share of total global transport fuel will increase from two percent today to 27 percent in 2050. Advanced renewable diesel fuels
Diesel Powers the U.S. Economy

will likely be the largest portion of this total, and be particularly important to decarbonize the fuel from heavy duty transport vehicles.35

DIESEL EQUIPMENT SALES, REPAIR AND SERVICING

Based on relative shares of diesel vehicles, equipment and fuel sold, and the number of employees within selected subsectors, the diesel sales, repair and servicing sector generated $82.1 billion in 2009 and employed 764,000 individuals.

A spin-off from developing and producing diesel technologies is the requirement to sell and service those technologies. Diesel engines are famous for their durability, truck engines have been reported to last more than a million miles. The ability and cost-effectiveness of rebuilding these engines makes such durability common. It also increases the relative importance of service delivery for diesel technology over an engine’s lifetime compared to other motive sources such as gasoline. Diesel services are generally embedded in other related industries for national income accounting purposes and services are often delivered through an outlet providing many other services, so separating the economic influence of diesel services is more difficult than for technologies and fuels. Automobile, truck and equipment dealers sell these products. Fuel stations and truck stops sell diesel fuel. Service departments, repair shops and diesel specialist’s service diesel equipment, rebuild engines and retrofit emission control devices. And leasing agents rent from large fleets of equipment.

Beyond the geographic concentration of manufacturing jobs, diesel technology creates jobs throughout the nation where diesel is used. Diesel bus and truck engine mechanics and diesel engine specialists are important green jobs which, according to a study by the Tomas Rivera Policy Institute, provide high-wage opportunities for non-European-Americans immigrants, particularly Latinos, to move up the American ladder.36

TRADE AND EXPORT IN DIESEL TECHNOLOGY AND FUEL

The U.S. exports a significant amount of diesel products and fuels; these commodities represented 4.4 percent of $1.06 trillion dollars in exports in 2009. Figure 14 shows how the $46.2 billion in diesel-related exports in 2009 were distributed among industrial sectors. These industries exported 8.9 percent of their diesel-related output, making their export-to-value ratio five times higher than the national average. Demand for these industries is driven by global trends; they bring in a larger share of the world market to the U.S. through trade. Refineries had the largest proportion of diesel-related exports, at $9.5 billion; truck manufacturers exported $9.1 billion, equal to 36 percent of their total production; construction equipment shipped-out 18 percent of its product, or $7.8 billion; engine manufacturers exported 22 percent or $6.9 billion.

Figure 14: Diesel Exports by Diesel NAICS Industries (2009) Billions $
REFERENCES

1 Minnesota IMPLAN Group Inc., 2011, IMPLAN U.S. data set for 2009
2 Alan Baum and Daniel Laura, Driving Growth: How Clean Cars and Climate Policy Can Create Jobs. Published by the Natural Resources Defense Council, United Auto Workers, and Center for American Progress, March 2010
3 Kiel, F., June Class 8 Truck Orders Top 20,000 for Eighth Straight Month, Transport Topics, July 11, 2011
4 R.L. Polk, Data provided to the Diesel Technology Forum, February 2011
6 R.L. Polk, 2011
7 Warburton, M., et al. 2007, p. 34
10 The Detroit Free Press, May 13, 2011


31 Ibid


33 Ibid

34 Department of Energy Biomass Program Outlook & Opportunities, Presentation by Paul F. Bryan, Program Manager, DOE Biomass Program, Advanced Biofuels Leadership Conference, Washington, DC, April 19, 2011


APPENDIX B: THE ECONOMIC BENEFITS OF USING DIESEL TECHNOLOGY

Diesel technology is the dominant motive force for the most fundamental of economic activities, growing food, building roads and houses, and moving goods to market. While the economic impacts from these services can be delineated in various ways, the bottom line is that without diesel technology, many of these tasks would be more costly and difficult. We turn now to how diesel is used to produce goods and services and the influence of diesel on the U.S. economy.

USING DIESEL TO PRODUCE BASIC COMMODITIES AND BUILD INFRASTRUCTURE

The U.S. economy is constantly evolving. Early in American history, the country was largely agricultural. As the country expanded, infrastructure needed grew. A desire to harness the country’s vast natural resources and obtain a better quality of life drove innovation. Technology was under constant development to increase productivity and efficiency. Many inventions have come and gone or been improved far beyond their initial capacity, however one could argue there are few that have lasted as long and grown as pervasive as the diesel engine.

Rudolf Diesel invented the diesel engine near the turn of the 20th century. One of the diesel engine’s greatest attributes is its ability to reach peak torque at low speeds, allowing for greater control and power for moving heavy loads at low speeds. As a result diesel became, and still remains, the power of choice in industries which need to move heavy loads from rest or up steep grades such as the mining or construction industries. Engine reliability, durability and efficiency are also prized, making it the cornerstone of other key sectors such as the farming and transportation sectors.

Figure 15 displays the key industry sectors – agriculture, construction, freight transport and transit – that rely heavily on diesel technology to deliver their products and services, and the percentage of value in the product facilitated through diesel technology use. Agriculture receives the largest infusion from diesel, at 35 percent, with coal mining and electric utilities incorporating about a quarter each.

Figure 15: Diesel’s Influence on U.S. Postal Service (2009)

Diesel technologies’ influences on these sectors is derived from the amount of total annual expenditures, including labor, rent, energy and capital stock, attributable to purchases of diesel machinery and vehicles, diesel fuel, and servicing of diesel equipment.
U.S. agriculture is among the most productive and economically valuable in the world. Diesel powers two-thirds of its equipment, moves 90 percent of its product and pumps one-fifth of its water. Agriculture spent $7.2 billion on diesel fuel in 2009, 58.2 percent of total agricultural fuel expenses. This represents about 2.5 percent of total costs incurred by the sector. In 2009, agriculture produced $330 billion in output, of which $27.2 billion was for farm sales, and contributed $176.6 billion to the nation’s GDP. U.S. output roughly equaled the output from the 35 European Union nations combined – $329 billion. The U.S. has 2,204,792 farms, which employ 1.4 percent of the labor force. In 2008, 2.1 million people were employed by the agriculture, forestry, and fishing industries. The added value of agriculture to the U.S. economy is estimated to be $365 billion. California led the nation in 2008, with $39 billion produced; Iowa and Texas followed.

Agricultural operations are quite varied, requiring a diverse array of vehicles and equipment. Since World War II, three significant events have transformed U.S. agriculture: the final transition from animal to tractor power; the application of advanced science, particularly agricultural chemicals; and the completion of large water supply storage and conveyance systems, which enabled intensive irrigation of U.S. farmland. These factors greatly increased per acre productivity and led to the emergence of larger, but fewer farms. In 1945 the U.S. had 5.9 million farms, with an average size of 195 acres. By 2007 the number of farms had dropped by 62 percent, while the average size had more than doubled to 418 acres.

Much of the agricultural sector’s success is attributable to the enhanced productivity derived through increased diesel mechanization of farming and processing. Yet while farming has become more mechanized, over the past three decades agricultural energy use has actually decreased. Agricultural energy use peaked in the late-1970s and declined throughout most of the 1980s. Yet between 1974 and 1994 food crop output rose by almost 80 percent. This energy use pattern in part reflects agriculture’s shift away from gasoline-powered machinery towards the use of more efficient diesel fuel. In 1974, gasoline accounted for approximately 50 percent of the energy supplied by fuels purchased on farms nationally, with diesel responsible for 38 percent. By 2005, when U.S. farms consumed 801 trillion Btus of energy, this relationship had flipped. Diesel fuel was responsible for more than 50 percent of this total, roughly 408.5 billion Btu, whereas gasoline only accounted for 16 percent. At the same time, output per energy unit rose over the period. Since 1990 there has been an increase in energy use, but by 2005, agriculture’s energy consumption was still below the peak of the 1970s.

The United States’ agricultural productivity helps make food inexpensive – a typical American family spends only about 5.6 percent of their household budget on food prepared and consumed at home. In 2008, U.S. farm output was 158 percent above 1948 levels. In the same period, aggregate input increased by only 0.06 percent per year, indicating that growth in farm output was mainly due to productivity increases. In addition to helping feed the nation, U.S. growers export a significant share of their production. In 2010 the nation exported $115.8 billion worth of agricultural products, 9.1 percent of total U.S. exports.

Today, U.S. agriculture relies on diesel fuel for a number of different applications, including:

- **Moving Commodities to Market** (e.g., Trucking) – In 2007, U.S. agriculture shipped in excess of

---

[^a]: Capital expenditures on diesel equipment were derived from the “capital” consumption listed under Institutional Demand in IMPLAN. IMPLAN does not directly allocate these capital expenditures to the consuming industries. To approximate the relative shares of these expenditures, the capital expenditures were allocated as intermediate goods to consuming industries in proportion to the other types of output provided from the source industry to the consuming industry.
$1.2 trillion worth of commodities, including cereal grains ($85 billion); animal feed ($90 billion); meat, fish, and seafood ($277 billion); milled grain products ($143 billion); other prepared foodstuffs ($479 billion); and other agricultural products ($143 billion). More than 90 percent of these items were shipped by truck, with rail and air accounting for most of the rest.

- **Planting, Cultivating, and Harvesting Crops, Tending Livestock (e.g., Off-Road Vehicles, such as Tractors and Combines)** – Diesel engines power more than two-thirds of all farm equipment in the United States. There's currently no cost-effective substitute for diesel for most tractor applications as a result of the inability of other fuels to provide sufficient power to pull the necessary equipment weight at slow speeds while providing remote portability.

- **Water Pumping** – In 2008, U.S. growers relied on 115,249 diesel-powered irrigation pumps, and spent more than $675 million to purchase the associated fuel, to deliver water to where it was needed. While diesel fuels only about 21 percent of the pumps used by agriculture, these represent the “swing” capacity that’s available during cyclical water-scarce periods to increase groundwater use and reduce reliance on surface water supplies. In 2008 diesel was used to power irrigation pumps on more than 10 million acres, compared to only 4.3 million with natural gas.

**MINING AND CONSTRUCTION: EXTRACTING MATERIALS AND BUILDING INFRASTRUCTURE**

Over 60 percent of mining, fuel production and construction equipment is diesel-powered. In the construction sector 98 percent of all energy use comes from diesel. The construction industry purchased $76 billion in diesel technology-related goods and services in 2009.

Mining and construction add considerable value to the U.S. economy. The mining industry mined $413.5 billion of product in 2007, adding $254 billion in value-added to the GDP in 2007, and $241 billion in 2009. The construction industry is even larger, creating $657 billion in value-added to the GDP in 2010. Construction industry spending that same year totaled $1.17 trillion.

In 2009, the nation’s mining, fossil fuel production and logging industry employed 641,000 people with a payroll of $54.9 billion; jobs were down from 730,000 in 2007, but payroll was up from $40.7 billion. The nation’s construction industry employed 7.6 million people with a payroll of $336 billion in 2007. Even in the wake of the recent recession in 2010 5.5 million workers held construction jobs.

The United States gets 93 percent of its energy from mined sources, such as petroleum, natural gas, coal and uranium and is among the world leaders in producing many of the most important mineral and fuel commodities. It is the world leader in sulfur mining, second largest producer of coal and natural gas, third for petroleum and is among the top three in cement, phosphate, copper, gold and lead. In 2008, the U.S. produced 1.17 billion tons of coal, 1.81 billion barrels of oil, 21.2 trillion cubic feet of natural gas, 1,950 tons of uranium and 8.25 billion tons of metallic and non-metallic minerals. The non-fuels mining industry produced $57.1 billion in 2009. Nevada was the leading producer with $5.5 billion, followed closely by Arizona with $5.4 billion.

---

b Most pumps are electric powered according to the U.S. Census of Agriculture.
This production requires some of the largest and most powerful engines available, making them dependent on diesel technology. By way of perspective, a coal mine shovel can scoop 120 tons in one bucket and a haul truck can carry 300 tons, powered by a 3,000 horsepower engine. The largest truck is 654 tons fully loaded, with a 3,650 horsepower diesel engine. In the largest pieces of equipment, the diesel engine powers electric generators that drive motors for each wheel and component, similar to train engines.

Similar to mining which provides minerals essential to a wide range of industries, construction is a core activity that resonates through the rest of the economy. Every building, power plant, reservoir, pipeline, roadway, airport factory and landfill must be constructed. All economic activity passes through or over a constructed structure. Recent policy initiatives at the federal and state level call for large investments in new renewable energy, electricity transmission and distribution, and high-speed rail systems, none of which can be completed without the use of diesel-powered construction equipment. For example, the Brattle Group estimates that $240 to $320 billion could be needed over the next 20 years to construct the new transmission grid required to deliver renewable power.

Concern over the state of America’s national infrastructure is growing. According to the American Society of Civil Engineers’ 2009 Report Card for America’s Infrastructure, an estimated $2.2 trillion must be spent over a five year period just to keep the existing infrastructure from crumbling. As the report states, “(y)ears of delayed maintenance and lack of modernization have left Americans with an outdated and failing infrastructure that cannot meet our needs”. The construction industry will be at the center of any investment in our nation’s infrastructure and as with agriculture and resource extraction, construction activity is dominated by diesel technology.

In 2008, construction consumed an estimated 862 trillion Btu, with 98 percent from diesel use. No viable alternative has yet emerged for motive applications that exceed 500 horsepower; some construction engines produce several thousand horsepower. Construction accounts for 55 percent of off-road fuel use. Other sectors, including agriculture, mining, industrial and airport ground support, make up the balance as shown in Figure 16. The construction industry used 18 percent of the medium-duty and 16 percent of heavy-duty on-road trucks in 2002.

**Figure 16: Off-Highway Fuel Consumption (2008 EPA NONROAD Estimate)**

---

1 The US EPA’s NONROAD 2008 model appears to produce results consistent with the EIA’s Adjusted Sales of Distillate Fuel Oil by End Use. The NONROAD model predicts total offroad use of 1,543 TBr and the EIA reports 1,434 TBr for the same categories. This situation differs substantially from the California Air Resources Board’s (CARB) OFFROAD model which had a substantially higher estimate of offroad fuel use compared to EIA and State Board of Equalization data for California. CARB is now recalibrating its model.

2 The Census Bureau discontinued the Vehicle In-Use Survey (VIUS) after 2002 which provided detailed descriptions and break downs of commercial vehicle use.
The value of construction work in 2007 was $1.15 trillion, falling to $815 billion in 2010. Figure 17 shows the patterns for residential, commercial plus industrial, and public construction for 1993 to 2010. Public construction has largely continued an upward trend since 2007, non-residential has been stable, while residential has fallen nearly 60 percent since 2006. Diesel technology is used to a greater extent for the heavy construction of roads, infrastructure and commercial buildings than for the lighter residential building. As a result, diesel equipment use has not fallen proportionately with construction activity as measured by dollar value.

**Figure 17: Annual Value of Construction Put in Place 1993-2010**

![Figure 17: Annual Value of Construction Put in Place 1993-2010](image)

**USING DIESEL TO DELIVER GOODS AND SERVICES: FREIGHT HAULING**

Once the crops are harvested or the minerals are extracted, these commodities need to be transported along our nation’s infrastructure, and without exception, the vast majority of all modes of goods movement are predominantly diesel-powered. This preference for diesel again comes from its higher thermal capacity (it gets more work out of the fuel), higher torque (capacity for heavy work) and ability to use less refined fuel, making it the “lifeblood” of our national economy.

According to the 2007 Commodity Flow Survey, 12.5 billion tons of commodities, valued at $11.7 trillion, were shipped within the U.S. diesel engines powered trucks, trains, ships and intermodal systems used to move 83 percent of $11.7 trillion in goods, and 85 percent of the 12.5 billion tons shipped in 2007. As seen in Figure 18, these goods are moved over long distances and through all regions of the country. Based upon the location of a product, its physical characteristics and the available infrastructure, goods will be moved on different modes of transportation, and in many cases, on more than one mode. Table 4 shows the value and tonnage by mode. As shown here, truck and rail are the predominant modes of transportation depending upon whether calculated by value or weight. Figure 19 shows the increase in the value of freight tonnage hauled from 1997 to 2007. For the diesel-dominated modes, truck and rail shares have increased significantly, while the waterborne share has decreased by a quarter.
NOTE to Figure 18: This map produced by the Federal Highway Administration shows the relative volumes moving over various thoroughfares in 2007, such as freight flowing down the Mississippi River and out of the Power River Basin coal mines.

Table 4: Shipments Characteristics by Mode of Transportation, 2007

<table>
<thead>
<tr>
<th></th>
<th>VALUE ($ MILLIONS)</th>
<th>%</th>
<th>TONS (THOUSANDS)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>All modes</td>
<td>11,684,872</td>
<td>100</td>
<td>12,543,425</td>
<td>100</td>
</tr>
<tr>
<td>Truck</td>
<td>8,335,789</td>
<td>71.3</td>
<td>8,778,713</td>
<td>70.0</td>
</tr>
<tr>
<td>Rail</td>
<td>436,420</td>
<td>3.7</td>
<td>1,861,307</td>
<td>14.8</td>
</tr>
<tr>
<td>Water</td>
<td>114,905</td>
<td>1.0</td>
<td>403,369</td>
<td>3.2</td>
</tr>
<tr>
<td>Air (including truck and air)</td>
<td>252,276</td>
<td>2.2</td>
<td>3,611</td>
<td>neg.</td>
</tr>
<tr>
<td>Pipeline</td>
<td>399,646</td>
<td>3.4</td>
<td>650,859</td>
<td>5.2</td>
</tr>
<tr>
<td>Multiple modes &amp; intermodal/1</td>
<td>1,866,723</td>
<td>16.0</td>
<td>573,729</td>
<td>4.6</td>
</tr>
<tr>
<td>Other and unknown modes</td>
<td>279,113</td>
<td>2.4</td>
<td>271,567</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Each mode of transportation has its own benefits, thus often times, multimodal or intermodal transportation is used to maximize goods movement efficiency. Intermodal transportation has increased 4.8 percent annually, as shown in Figure 20, as the fuel economy benefits of diesel-powered rail haul over long distance is combined with the portability and flexibility of smaller diesel truck-trailer combinations to disperse freight deliveries. When combined with marine transport – also dominated by diesel engines – the ability to transport freight in a single container provides significant handling and security advantages for shippers and customers. Key rail lines on the West Coast includes those which transport containers and truck trailers to and from the Ports of Long Beach, Los Angeles and Oakland, and locations throughout the United States, particularly the Midwest and East Coast, where goods are then transported by truck due to the lack of direct accessibility to the rail lines.

The widening of the Panama Canal, projected to be completed in 2014 could change the relative balance of national freight movement as larger ships can move easily between the coasts. The largest vessels’ freight capacity is projected to increase by more than two and a half fold. This will accommodate many more container ships, and intermodal traffic from Asia may now bypass the West Coast ports and go straight to East Coast and Gulf destinations. Relative shares of port calls and rail-hauled freight are expected to shift, and truck traffic should be redistributed on the nation’s roadways.
Altogether, the U.S. freight hauling and warehousing industry consists of more than 219,000 companies that employed nearly 4.5 million individuals with a payroll of $173.2 billion in 2007. These transportation sectors spend $46 billion on diesel technology inputs, 7.2 percent of their total revenues. Employment in the transportation sectors that use diesel technology is shown in Figure 21. Trucking is the largest sector, employing more than one and a quarter million individuals. The rest of this appendix will provide a more detailed look at each of these transportation modes and their contribution to the U.S. economy.

Figure 21: Transportation-Related Employment: Provision of Diesel Technology (2009)

The Role of Trucking in the National Economy

The vast majority of commercial trucks—including those used by independent trucking companies and “fleets” (e.g., store- and distributor-owned trucks) – rely on diesel-powered engines. Trucks transport 70 percent of the nation’s goods by weight and 71.3 percent by value. The transportation and warehouse sector was responsible for $390 billion of the nation’s total gross product in 2009. The trucking industry supports an annual payroll of $57 billion dollars.

Truck transportation, provided by the trucking sector itself, and embedded as a core function in other individual business sectors, such as warehousing and retail stores, is the backbone of nation’s economy. Trucks transport almost all of the inputs upon which America’s family farms rely. What’s more, almost every commodity at one time or another travels – from warehouse to store or ports to rail stations – by truck. Simply put, without trucks the U.S. economy does not move.

Despite ubiquitous rhetoric about the “information highway”, it is the inter- and intrastate highways that actually link goods and services together. Because trucks carry a large majority of our nation’s goods, truck hauling mileage increases nearly in lockstep with the U.S. economy. Figure 22 shows how heavy-duty single-unit truck mileage increased 3.0 percent on an annual basis from 1998 to 2008, and combination (i.e., semi-tractor with trailers) truck mileage increased 3.8 percent on an annual basis, while the GDP rose 2.6 percent annually in the same period.

As noted earlier, more than 90 percent of these types of trucks are diesel-fueled. Figure 23 shows how highway diesel fuel use has grown since 1980, tripling to 39 billion gallons by 2008, almost all of which is used to fuel freight-hauling trucks.

---

THE ROLE OF TRUCKING IN THE NATIONAL ECONOMY

The vast majority of commercial trucks—including those used by independent trucking companies and “fleets” (e.g., store- and distributor-owned trucks) – rely on diesel-powered engines. Trucks transport 70 percent of the nation’s goods by weight and 71.3 percent by value. The transportation and warehouse sector was responsible for $390 billion of the nation’s total gross product in 2009. The trucking industry supports an annual payroll of $57 billion dollars.

Truck transportation, provided by the trucking sector itself, and embedded as a core function in other individual business sectors, such as warehousing and retail stores, is the backbone of nation’s economy. Trucks transport almost all of the inputs upon which America’s family farms rely. What’s more, almost every commodity at one time or another travels – from warehouse to store or ports to rail stations – by truck. Simply put, without trucks the U.S. economy does not move.

Despite ubiquitous rhetoric about the “information highway”, it is the inter- and intrastate highways that actually link goods and services together. Because trucks carry a large majority of our nation’s goods, truck hauling mileage increases nearly in lockstep with the U.S. economy. Figure 22 shows how heavy-duty single-unit truck mileage increased 3.0 percent on an annual basis from 1998 to 2008, and combination (i.e., semi-tractor with trailers) truck mileage increased 3.8 percent on an annual basis, while the GDP rose 2.6 percent annually in the same period.

As noted earlier, more than 90 percent of these types of trucks are diesel-fueled. Figure 23 shows how highway diesel fuel use has grown since 1980, tripling to 39 billion gallons by 2008, almost all of which is used to fuel freight-hauling trucks.
The 2010 *Annual Energy Outlook Reference Case* forecasts that truck fuel use will grow 35 percent by 2035 to 2.7 million barrels per day.\textsuperscript{51} Such a forecast, is based in part on assumptions about the continued relationship between heavy-duty truck fuel use and GDP as discussed earlier and shown in Figure 5 on page 9 of the Executive Summary.

**Figure 22: U.S. Truck Miles Travelled (1980-2008)**

In addition to its central role moving the U.S. economy, the trucking sector itself contributes substantially to the nation’s prosperity through spending and employment. Approximately 118,500 family- and corporate-owned trucking businesses operated in the U.S. in 2007, directly employing about 1.48 million Americans.\textsuperscript{52} Many of these jobs come from small and family-owned businesses. Four-fifths of firms in the trucking and warehousing sector employ fewer than 10 people. Likewise, 91 percent of all truck companies generate revenues of less than $5 million a year.\textsuperscript{53}

The trucking industry also makes substantial contributions to federal, state and local tax revenues. For example, in 2007 an operator of a typical five-axle tractor semi-trailer paid $4,930 per year in state charges, and $13,889 annually in highway taxes.\textsuperscript{54}
FREIGHT TRANSPORTATION BY RAIL

Rail is responsible for approximately 37 percent of the total ton-miles carried by various transportation modes (e.g., trucks, ships, pipelines and aircraft). The nation’s 565 freight railroads employed 183,700 individuals, and pay wages and benefits averaging $98,500 per employee. The industry delivered $30.8 billion in value added or national income in 2009.

Railroads reduce highway congestion – by shifting traffic away from trucks – and provide shippers with a cost-effective way of transporting their goods. In the 1950’s diesel rather than steam engines became the preferred source of power for locomotives. Unlike steam engines, diesels were more powerful, cleaner, required less refueling and less repair. Today diesel still powers virtually all of the locomotives hauling freight in the U.S.

Railroads provide essential transport for a number of key commodities. In 2008, the nation’s railroads hauled 1.8 billion tons of freight valued at $388 billion listed in Figure 24, with coal comprising the largest tonnage (45 percent) followed by farm products (8.7 percent). Coal and mineral hauling relies on rail because of the large volumes that can be moved cost-effectively over very long distances between fixed points such as mines and power plants or steel foundries. For example, the Powder River Basin rail line, powered by diesel locomotives, carried 194 million tons of coal in 2006, using up to 80 trains a day, each a more than a mile long. Similarly, moving chemicals by rail achieves efficiencies while isolating this freight from on-road traffic.

The seven Class I railroads operate almost 119,000 miles of track, including trackage rights. Regional railroads operate 19,500 miles, and local railroads another 24,000 miles. Nationally, the two largest railroads, BNSF and Union Pacific, generated $16.85 billion and $16.96 billion of revenues respectively in 2010. Figure 25 shows how the diesel locomotive population in Class I railroad fleets declined for a period, as locomotives became more efficient, and then grew again, reaching 24,000, as the amount of freight hauled increased dramatically. Locomotive efficiency improved from 235 ton-miles per gallon in 1980 to 480 ton-miles per gallon in 2009; revenue ton-miles (i.e., tons times miles moved) more than doubled from 1981 to 2008. The EIA forecasts that even though ton-miles of freight hauled by rail could increase by 50 percent by 2050, total railroad fuel use could fall by 15 percent to 40 percent.

Figure 24: Key Commodities Hauled by Rail, Millions of Tons (2008)
WATERBORNE AND MARINE FREIGHT TRANSPORT

About 78 percent of the ships that haul freight are diesel-powered.67 Virtually all of the bulk carriers including river barges that transport oil, ore, wheat and other goods are diesel-powered. So are the containerships that transport the majority of all manufactured imports and exports. Over the past decade, the water transportation industry employment ranged from 52,600 in 2002 to a peak of 66,800 in 2008,68 with a payroll of $4.47 billion in 2009.69 Economic value added was $14.3 billion in 2009.70

The United States is the world’s largest importer and exporter of goods. The great bulk of the goods imported into or exported from the nation move by ship. The engines that power these bulk carriers and containerships are the world’s largest diesels, some reaching in excess of 80,000 horsepower. Typically ocean-going container vessels, tankers and other large ships utilize diesel engines burning residual fuel oil, a heavier and denser fuel than diesel fuel, whereas most all work boats, barges and inland waterway vessels rely on diesel fuel.

As noted earlier, waterborne shipping moved about one percent and 3.2 percent of U.S. freight (not including intermodal transport) measured by weight and value, respectively. Figure 26 shows the growing importance of international trade shipped by marine vessel, reaching 1.5 billion tons in 2008, almost double 1983 levels. Domestic tonnage has declined slightly, as intermodal and other modes have increased their shares. Petroleum is the primary good both exported and imported, measured by tonnage.71 Agricultural products are the next largest exports, with manufactured goods following.
By total tonnage, nine of the world’s 10 busiest ports in 2009 were located in Asia; South Louisiana (#12), Houston (#13), and New York/New Jersey (#23) were the busiest American ports. All told, 184 U.S. ports handle more than a quarter-billion tons of freight. Figure 27 shows the value of waterborne commodity flows by state of origin and destination. Gulf Coast, Great Lakes and Mississippi River states are the top four for origination, showing the importance of both inland and marine transport. Louisiana is dominant in both categories because it is the gateway to the Mississippi River, plus it has a large number of oil production and refining facilities.

As discussed previously, intermodal is a large and growing share of both truck and rail freight hauling. In 2009, the U.S. imported about 1.4 times as many containers as it exported internationally by ship. By container traffic, the busiest U.S. ports are Los Angeles (#16), Long Beach (#18), and New York/New Jersey (#21) – reflecting the importance of intermodal transport in these regions, in which containers are shipped by not only water, but also rail and road.

The Army Corps of Engineers monitors and maintains 12,000 miles of inland and intracoastal waterways. Barge traffic on the Mississippi and its tributaries, the Columbia and Snake Rivers, and the Great Lakes are the nation’s main freshwater freight passages. Virtually all barges and tugs using these waterways are diesel driven.
Diesel is a prime mover for the predominant transit modes. Approximately 71 percent of transit buses are fueled by diesel. Of commuter rail, 58 percent of passenger-miles are provided by diesel-fueled trains. The transit, and local and interurban personal transportation industry employs 416,000 people, with a payroll of $10.5 billion in 2009. About three-quarters of these individuals are employed by private firms providing ground passenger and school bus transport; the other quarter are employed by local government transit agencies. The industry delivered an economic value added of $41 billion in 2008.

Diesel moves more large groups of people on the ground and over water than any other motive power. Like trucks and freight rail, a majority of buses and commuter rail are diesel-powered, due in large part to diesel’s fuel efficiency relative to gasoline. Compared to natural gas, diesel also offers benefits in terms of its energy density, and the availability and ease of fueling. Over the last few decades, several transit agencies have invested in natural gas buses, predominantly due to their historically lower emissions. Although the relative cost of natural gas to diesel fuel currently favors the former, the high cost of establishing the fueling infrastructure together with the reduced emissions from today’s clean diesel technology has led to diesel’s continued dominance in this sector (see insert for more information on diesel vs. natural gas buses).

COMPARING NATURAL GAS AND DIESEL APPLICATIONS

Over the past decade, compressed natural gas (CNG) powered buses, concrete mixers, refuse haulers and, especially, delivery trucks have become competitive with diesel-fueled engines. Initially, natural gas engine technology had lower overall emissions compared to diesel, however since 2010 new generation diesel engines are on par with natural gas emissions. For example, new diesel engines emit over 98 percent less particulate matter (PM) and 95 percent less nitrous oxides (NOx) than engines built only a decade and a half ago. The primary driver for more recent interest in natural gas is lower fuel prices and expanded use of domestic energy sources instead of imported oil. However, for a variety of reasons, it seems likely that natural gas engines will have to overcome some barriers to gain a larger market share. Natural gas-powered heavy-duty trucks have experienced complaints from truck drivers that the liquefied natural gas (LNG) engines have a noticeable loss of power compared to diesel-fueled vehicles. Likewise, without an extensive fueling network, natural gas vehicles have a limited driving range – 400 miles compared to 1,000 miles for a comparable diesel heavy-duty truck. The Energy Information Administration did not foresee wider adoption of CNG-powered trucks in its 2010 Annual Energy Outlook: “HDNGVs cannot gain a major share of the heavy truck market in the absence of major investments in natural gas fueling infrastructure.”

Recent technological advances, as well as cost and safety concerns, may act to muffle the adoption rates for CNG-powered transit buses. These vehicles are not as fuel efficient as diesel engines: one gallon of LNG contains roughly 60 percent of the energy in a gallon of diesel fuel. CNG contains even less energy per unit volume. Natural gases’ lower energy density can be addressed by using larger fuel tanks, but that imposes a fuel economy penalty due to the added weight, and may reduce the vehicle’s useable cargo capacity.

In addition, natural gas poses potentially greater safety hazards than diesel. The National Fire Protection Association gives natural gas its highest hazard ranking for flammability, while diesel is designated as moderately flammable. The extreme pressure and temperature conditions involved in storing and using CNG and LNG creates risks not encountered with diesel.

With recent technological advances, as well as cleaner diesel fuels, state-of-the-art diesel vehicles have become as low-emission as CNG buses. Emerging diesel hybrid technology seems poised to provide significant reductions in fuel consumption relative to the present fleet, thus displacing the apparent need for NGV trucks.
As an alternative to natural gas buses, several communities looking to green their fleet or reduce petroleum consumption are looking to using diesel hybrid buses. Studies by the National Renewable Energy Laboratory have shown diesel hybrid buses to improve fuel economy anywhere from 25 to 50 percent. In addition, they have been found to have lower maintenance costs. According to the Center on Globalization, Governance and Competitiveness, diesel electric hybrid buses surpassed natural gas buses as the preferred alternative to traditional diesel buses in 2009.

Table 5 shows the number of vehicles and the proportion powered by diesel engines as well as the passenger-miles by each mode. Transit ridership has not grown as fast as other transportation modes. Nevertheless, passenger-miles have risen from 40 billion to 55 billion since 1990, as shown in Figure 28. As one would expect, public transportation ridership tends to grow in proportion to increasing fuel prices. According to the American Public Transportation Association, public transit ridership peaked at 10.7 billion in 2008 when gasoline prices reached their highest level. Based on these breakdowns of the transit trips made in 2008, 85 percent of transit vehicles and 49 percent of transit passenger-miles were diesel-powered.

Table 5: U.S. Transit Vehicles and Travel (2008)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Vehicles</th>
<th>Diesel</th>
<th>Passenger Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Bus</td>
<td>48,005</td>
<td>82.8%</td>
<td>21,198</td>
</tr>
<tr>
<td>Vanpool</td>
<td>5,133</td>
<td>4.7%</td>
<td></td>
</tr>
<tr>
<td>Demand Response</td>
<td>12,676</td>
<td>55.6%</td>
<td>844</td>
</tr>
<tr>
<td>Jitney</td>
<td>135</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Trolleybus</td>
<td>622</td>
<td>3.8%</td>
<td>161</td>
</tr>
<tr>
<td>Light Rail</td>
<td>1,901</td>
<td>1.5%</td>
<td>2,081</td>
</tr>
<tr>
<td>Commuter Rail</td>
<td>5,613</td>
<td>58.0%</td>
<td>11,032</td>
</tr>
<tr>
<td>Commuter Rail Locomotive</td>
<td>702</td>
<td>90.1%</td>
<td></td>
</tr>
<tr>
<td>Heavy Rail</td>
<td>11,022</td>
<td>0.0%</td>
<td>16,850</td>
</tr>
<tr>
<td>Other Rail</td>
<td>101</td>
<td>13.0%</td>
<td></td>
</tr>
<tr>
<td>Ferryboat</td>
<td>21</td>
<td>100.0%</td>
<td>390</td>
</tr>
</tbody>
</table>

There are approximately 1,200 transit agencies with bus fleets. In 2009, local transit agencies collected $11.86 billion in fare revenues. Operating expenses totaled $34.6 billion, with salary, wages, and benefits of $23 billion. About 1.2 percent of trips are made on local public transit, 0.2 percent on commuter buses, and another 1.7 percent on school buses. Of trips made on local public buses, 17.4 percent were for commuting to work. School buses moved 23.4 million students each school day during the 2008-2009 school year, covering 3.9 billion miles. School bus companies employed 180,000 people.

Average annual growth in demand for new transit buses in North American is expected to be 6.1 percent through 2017. The U.S. transit bus market is served by only five manufacturing firms. Four of these five companies are U.S. firms or U.S. subsidiaries of foreign firms, which, based upon an industry multiplier, provide between 25,000 and 33,000 jobs. Although this number is not large, they are spread across virtually every state in the eastern U.S. with highest concentration in Indiana, Michigan, Ohio and Pennsylvania.
Motor coaches used for intercity, scenic and sightseeing drove 58 million passenger-miles in 2010, about 10 percent more than for transit. The industry maintained 35,000 buses, which consumed 320 billion gallons, almost all diesel, at an average fuel economy of 5.6 miles per gallon. The motorcoach industry employed 127,000 individuals in 2009, according to the American Bus Association Foundation, with a payroll of $6.9 billion on an output of $10 billion.

Most Amtrak passenger trains are hauled by diesel locomotives outside of the electrified Northeast Corridor. Amtrak carried 6.2 million passenger miles in 2008, using 278 locomotives pulling 1,177 passenger cars. Over the 1998 to 2008 period, Amtrak ridership rose 16 percent, but it rose 14 percent in the last two years of that period as gasoline prices jumped.

**DIESEL: A PRIME SOURCE OF INDUSTRIAL SITE, REMOTE AND BACK-UP ELECTRICAL POWER**

Diesel generators’ high reliability and low cost make them the technology of choice to supply back-up power in large buildings, shopping malls, hospitals, universities, waste water treatment facilities and factories, among other locations. For the most part, back-up generators are seldom operated; the equipment is typically installed to serve during internal emergencies or an electricity grid failure.

Diesel engines also are relatively portable, reliable and durable, making them the technology of choice to meet temporary power needs or for primary power in locations such as remote Alaskan villages that are beyond the reach of the electricity grid. U.S. EPA estimates that 1.15 million engines were in stationary use in 2008.

As indicated in Figure 29, about 26,500 megawatts (MW) of dispersed and distributed generation is located at commercial and industrial premises. Of this, 14,000 MW – 1.3 percent of total U.S. generation capacity – consists of

**USING CLEANER DIESEL TO PROVIDE STANDBY AND EMERGENCY POWER GENERATION**

In 2005 San Diego Gas and Electric Company adopted the Clean Gen program, in which up to 25 MW of existing back-up generators were upgraded and made available for deployment during periods of peak electricity demand. Engines located at different facilities were outfitted with California Air Resources Board-approved filters that lowered particulate matter emissions by 85 percent, and significantly reduced carbon monoxide and hydrocarbon emissions. The generators have become an integral part of the utilities’ power management system, supplying roughly 17 MW of electricity in 2007 to address energy shortages caused by multiple Southern California wildfires. Similarly, Portland General Electric has engaged more than 40 MW of standby generation at customer sites to address peak demand.
internal combustion engines (ICE), often compression ignition. Dispersed generation, 93 percent of which are ICEs, is typically remotely located from the utility grid. For most of these applications, the generator is the sole power source. Distributed generation, on the other hand, is interconnected with the utility system, and generally used to manage customers’ load or produce thermal byproducts, such as steam or hot water. ICEs account for 27 percent of these generation plants, but because these are grid-connected, many are natural-gas fueled with spark-ignition. Still, a significant number are diesel-fueled back-up generators relied on in emergencies when gas pipelines also may stop flowing.

Figure 29: U.S. Dispersed and Distributed Generation Technology Capacity (2010)

**DIESEL POWERS GOVERNMENT**

The federal as well as state and local governments manage extensive fleets of diesel vehicles and equipment. About half a million vehicles (excluding military vehicles) were operated by the federal government in 2009, making it the largest vehicle fleet in the world. Along with highway service and vocational vehicles, construction machines, transit buses, land maintenance-related (e.g., tractors) and emergency vehicles, the government also owns industrial back-up diesel generators for public works projects. According to the General Services Administration, approximately 60 percent of these vehicles are trucks, buses and ambulances with fewer than 40 percent being passenger vehicles. As one component of this fleet, the federal government maintains about 120,000 medium and heavy-duty trucks, most of which are diesel-powered. Diesel fuel use by the federal government fell from 2000 to 2006, but recently rose to 83 million gallons in 2009, with biodiesel nearing 10 percent of total consumption, as shown in Figure 30.
MILITARY OPERATIONS

The military heavily relies on off-road diesel engines for its training and overseas activities. The U.S. government accounts for two percent of energy use in the United States. The Department of Defense accounts for 80 percent of this total, with the Navy accounting for one-third of that.95

The military maintains extensive fleets of tactical and nontactical vehicles and vessels. The composition of these fleets are extremely varied. While a detailed look at these fleets are beyond the scope of this paper, we know that many of them are diesel-powered based on the fuel usage figures cited above. For example, according to the National Defense Intelligence Agency, the Army and Marine Corps have more than 300,000 tactical trucks, more than 80 percent of which are owned by the Army.96 A Defense Department study found 360,000 diesel engines used more than 83 percent of the fuel powering U.S. Army and Marine Corps vehicles and generators, with the remainder going to the Abrams battle tank, which is powered by a gas turbine.97 The Navy has another 700 diesel engines in its fleet of 285 vessels.98

Diesel fuel No. 2 (DF-2) and Jet Propellant 8 (JP-8) – a kerosene-based propellant used to operate off-road vehicles, tanks, jets and even field stoves – are the two most common fuels used in the military. In 2009, the Department of Defense purchased 21.2 million barrels of distillates and diesel and 57.6 million barrels of JP-8.99 The two fuels have different properties that prevent them from being substitutable. In the 1990s, the Department of Defense (DOD) transformed its land-based fleet to run on diesel. Under DOD Directive 4140.43, also known as the “one fuel forward” policy, to improve logistics and efficiency, the military is investigating how to create one distillate fuel that could serve both aviation needs and ground vehicles. A main concern driving this research is the future need for commercial diesel engines used in the military to meet EPA 2010 emission standards, resulting in more fuel-sensitive engines in the field.100

Commitments to use more renewable fuels within the military are strong. The army is seeking to use 25 percent renewable energy by 2025 while the Navy is hoping to use renewable fuels for 50 percent of its energy needs by 2020. The Air Force is also planning to fly on a 50-50 blend of renewable and conventional fuels by 2016. Based on current estimates, achievement of the Navy and Air Force goals would result in the purchase of over 700 million gallons of renewable fuels each year.101
STATE AND LOCAL GOVERNMENT

State and local governments managed 3.8 million vehicles, plus a quarter million trailers in 2009. Of these, 485,000 were buses and 1.9 million were trucks, ranging from light-duty to tractor-trailers to emergency response.

State and local governments spent $338 billion on public works activities in 2007, most of which is captured in the discussion of construction activity in this report. Likewise, the federal government invested $73 billion in fiscal year 2007 on transportation, most of which was disbursed to state and local governments for various projects.

PUBLIC SAFETY AND PROTECTING PROPERTY

Diesel technology drives many of the vehicles necessary to ensure public safety. As with other applications, diesel provides greater hauling capability than equivalently-sized gasoline engines, and diesel fuel is less volatile, and thus safer in the critical situations where emergency vehicles are used. Diesel engines also are more reliable and durable than gasoline engines, particularly for the heavy-duty applications associated with fire fighting and emergency response. Fire trucks also double as water pumps, where the power output advantage of diesel is important for moving vast quantities of water quickly. In the wake of a variety of natural disasters, such as earthquakes and floods, diesel power is essential to the restoration of public services, removal of debris, stand-by power for emergency uses, and reliable, off-road transportation. Due to the “double duty” pulled by many diesel vehicles and engines, (e.g., bulldozers used for multiple purposes such as both construction and flood-levee maintenance or wildfire control) any accounting will underestimate the actual importance of diesel technology in these roles.

The most common discreet use of diesel in public safety is for the provision of fire protection. Almost all fire-fighting vehicles are diesel-powered due to the combination of power, reliability and fuel-handling safety. In 2009, the U.S. suffered 480,500 structural fires that caused $10.8 billion in damages. 2,695 people died in those fires, and 14,470 were injured. However, these represent a 6.7 percent decrease in the number of fires from the previous year, and are part of a continuing steady decrease in fires over the past 30 years. To protect against fires the U.S. spent an estimated $362 billion on fire protection services in 2008. Firefighting agencies employed 329,603 full time employees and 99,752 part-time employees in 2009. According to the National Interagency Fire Center, from 1999 to 2010, there was an annual average of 79,000 wildland fires covering 6.5 million acres. The U.S. Forest Service maintained 1,160 fire engines in 2008 to battle blazes on its holdings, 495 of those being medium and large using diesel engines, and the smaller ones most likely being diesel.
REFERENCES


12 Natural Resources and Environment Division, 1995, Agricultural Resources and Environmental Indicators, Production Inputs, Washington, DC: U.S. Department of Agriculture, 135-136


18 Ibid

19 Diesel Technology Forum, 2011, New 2011 Clean Diesel Technology for Farm and Construc-


38 Ibid

39 2009 Transportation Energy Data Book, Table 5.7, p. 5-8


Ibid

2009 Transportation Energy Data Book, Appendix A

American Public Transportation Association, 2010 Public Transportation Vehicle Database, Washington, DC, June 2010


APTA, 2010


School Bus Fleet, 2011, School Bus Fleet 2011 Fact Book, Torrance, CA
86 Lowe, Marcy; Aytekin, Bengu; Gereffi, Gary, 2009, Public Transit Buses: A Green Choice Gets Greener (Chapter 12), Center on Globalization, Governance and Competitiveness, Manufacturing Climate Solutions: Public Transit Buses, p. 27


90 2009 Transportation Energy Data Book, Table 9.10, p. 9-11


94 2009 Transportation Energy Data Book, 2010


This section of the report identifies key federal and state policies impacting demand for new diesel engines and technology as well as those policies that impact the existing fleet of diesel engines and equipment and federal and private research investments.

Over the past decade, laws and regulations in the United States have been focused primarily on reducing emissions of smog-forming compounds and fine particles from a variety of sources, including diesel engines of all kinds.

Regulatory pressure is now shifting to greenhouse gas emission control and new public policies adopted at the state and federal levels will significantly shape the future of fuels and technologies for transportation and industrial use. Compared to Europe, U.S. environmental policies tend to be more aggressively focused on a broad range of air emissions, but are far less rigorous regarding greenhouse gases (GHG). However, passage of California’s landmark Assembly Bill 32 (the Global Warming Solutions Act), combined with higher gasoline prices, are fostering a broader scope of regulations and a more diverse set of fuels being used for transportation, construction, cultivation and electricity generation.

Advanced diesel technology increasingly outperforms competing equipment in terms of efficiency, power output and flexibility. While diesel engines tend to have lower greenhouse gas emissions than other fuel technologies – on a well-to-wheel lifecycle basis, diesel fuel use generates less CO₂ per unit of energy than gasoline – they typically have had higher emissions of other pollutants. Recently however, diesel technology has established a new capability of low-emissions environmental performance, enabling it to play a greater role in reducing all emissions as well as petroleum consumption. As compared to some other technologies, diesel’s value is further enhanced through the immediate readiness of the technology and extensive fuel distribution network. Coupled with its suitability to use a wide range of renewable fuels, diesel technology provides substantial opportunities for delivering near term GHG reduction and fuel saving benefits.

**FEDERAL REGULATORY POLICIES**

The key federal and state policies that are acting to create demand for advanced diesel technology include:

- **Corporate Average Fuel Economy Standards 2012-2017 and 2017-2025** – Under the Energy Independence and Security Act of 2007, the U.S. Environmental Protection Agency (U.S. EPA) and National Highway Traffic Safety Administration (NHTSA) have developed fuel-efficiency standards requiring that automakers, beginning with 2012 model vehicles, have to improve their fleets’ fuel economy and cut GHG emissions by roughly five percent annually, with a goal of achieving a 34.1 miles per gallon average fleet wide fuel economy for all new vehicles sold in the U.S. by 2016. The policy also established a 250 grams per mile national GHG emission requirement, or approximately 25 percent less than the emissions produced by vehicles today.

  On July 29, 2011, a new proposed rule was announced that beginning in 2017 would further increase corporate average fuel economy (CAFE) standards to as much as 59.5 mpg by 2025. More efficient diesel engines become more attractive as a cost-effective technology option for achieving fuel economy standards while maintaining performance.

- **Fuel-Efficiency Performance Requirements for Medium- and Heavy-Duty Vehicles** – U.S. EPA and NHTSA have issued final rules establishing the first-ever regulation of fuel economy for medium- and heavy-duty commercial trucks and buses. The rule establishes progressive performance standards that will require further efficiency gains ranging from seven percent to 23 percent depending on vehicle size and configuration, beginning in 2014. Diesel engines are

the primary power source for this diverse population of regulated vehicles, and this rule will require further efficiency improvements, spurring new investments in diesel engine research and development.3

- **The Renewable Fuel Standard (RFS) Program** – The RFS program was originally created under the U.S. Energy Policy Act of 2005, which established the nation’s first renewable fuel volume mandate. The original RFS program required that 7.5 billion gallons of renewable fuel be blended into gasoline by 2012. Under the Energy Independence and Security Act of 2007, the RFS program was expanded to include diesel, in addition to gasoline; the volume of renewable fuel that has to be blended into transportation fuel was increased to 36 billion gallons by 2022; and U.S. EPA was directed to apply lifecycle greenhouse gas performance threshold standards to ensure that each category of renewable fuel emits fewer greenhouse gases than the petroleum fuel it replaces. Taken together, RFS provides a significant incentive for the production of biodiesel and advanced biofuels.b

In addition to spurring demand for more fuel-efficient diesel technologies, other regulatory policies are serving to encourage lower-emissions, as follows:

- **U.S. EPA’s Clean Air Non-Road Diesel, Tier 4 Emissions Standards** – Adopted in 2004, it is the fourth generation of emissions standards and reduces exhaust emissions from non-road diesel engines by integrating engine and fuel controls as a system. To comply with the multi-phase program, cleaner, ultra-low sulfur diesel fuel is required and engine manufacturers are producing engines with advanced emission-control technologies, similar to those being used on highway trucks and buses. Under the regulation exhaust emissions of nitrogen oxides (NOx) and particulate matter from these engines will decrease by more than 90 percent as the standards are fully implemented through 2015.

- **U.S. EPA’s 2008 Marine Diesel Vessel Ruling** – Created the first national emission standards for remanufactured marine diesel engines that are larger than 600 kilowatts (kW). The ruling launched a three-part program to reduce emissions from marine diesel engines below 30 liters per cylinder displacement. Marine propulsion engines used on vessels such as recreational and small fishing boats, towboats, tugboats and Great Lakes freighters, as well as marine auxiliary engines ranging from small generator sets to large generator sets on ocean-going vessels, are subject to the rule, which aims to cut particular matter (PM) emissions by as much as 90 percent and NOx emissions by as much as 80 percent.

- **U.S. EPA regulations** require that **diesel-fueled reciprocating internal combustion engines (RICE)** – principally used as back-ups for electricity generation for more than 15 hours annually – to be fitted with pollution reduction technology by 2013.

**INFLUENTIAL STATE AND LOCAL REGULATIONS**

Beyond federal requirements, state governments are also pursuing environmental, climate and energy policies that impact diesel technology. Most notably, California has adopted a number of policies that will impact the future of diesel technology, including:

- **Low-Carbon Fuel Standard (LCFS)** – which mandates GHG standards for transportation fuels,

- **Assembly Bill (AB) 1493 (Pavely II)** – which requires GHG fuel economy standards for light-duty vehicles, and

- **AB 32 “The Global Warming Solutions Act”**— which calls for steep reductions in GHG emissions economy-wide.

Other states have followed California’s lead related to low-emission vehicle requirements and GHG emission standards, including New York, New Jersey, Massachusetts and Pennsylvania.4 Several northeastern and Mid-Atlantic states have been working together in recent years to develop a comprehensive, regional low carbon fuel standard. In addition, six states and four Canadian provinces have joined California in the Western Climate Initiative to develop joint climate change policies, although no specific enforceable laws, regulations or plans have been adopted yet.5 How these policies will ultimately impact diesel use is unclear. Shifting to more ef-
Efficient diesel from gasoline may be a cost-effective means of gaining the 10 percent reduction under the LCFS. Similarly, diesel cars can more easily reach the fuel economy standard. On the other hand, the objective of these initiatives is to reduce all petroleum use, including diesel. Electrification that displaces diesel and gasoline use is a stated objective of CARB.

In addition to state and federal policies, local regulations and market-based initiatives are also influencing diesel technology. For example, there is a trend towards environmentally sustainable construction processes, in which lower emissions and energy consumption practices are adopted as part of publicly funded and some privately funded construction activities. These policies – established through contracting provisions and local ordinances – typically establish emissions performance and operational requirements designed to lessen the environmental impact of construction equipment activity as part of the project. The most aggressive approaches require equipment of certain emissions levels or require the modernizing and upgrading (retrofitting) of any existing equipment to be included in the bid process. Some efforts have also specified the use of renewable fuels such as biodiesel. Although California has a regulation mandating the retrofitting of construction equipment in the state as part of its larger Diesel Risk Reduction Plan affecting all diesel vehicles and equipment in the state, these “clean construction” specific requirements have been adopted by jurisdictions in New York, Illinois, Rhode Island and California.6

Over the long-run, as emission goals are achieved, public policies are likely to become less important in driving the evolution of diesel technologies, replaced by more purely economic considerations (e.g., fuel efficiency).

WHERE IS DIESEL HEADED? INVESTMENT IN TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION

Investment in diesel engine and fuel technology at the public and private sector has been increasing. U.S. companies spent $234 billion domestically on research and development (R&D) in 2008. Machinery and non-aerospace manufacturing companies, the primary producers of diesel technology, spent about $25 billion.7 In addition, federal, state, local and joint programs have accelerated the spread of clean diesel technology to improve the environment while still delivering all of the benefits unique to diesel.

DIESEL INDUSTRY RESEARCH AND DEVELOPMENT

The diesel industry has invested large sums of money into R&D over the past few years largely to comply with new exhaust emissions standards. Although it is not possible to isolate all diesel-specific research, a significant share of the expenditures of the leading manufacturers is likely to be attributed to enhancements to diesel engine technology and emissions control. Diesel technology companies are directly involved in engine manufacturing; automotive companies produce vehicles; and chemical/general companies rely on diesel technology to produce a diverse array of products. On average, the automotive industry has the highest level of R&D expenditures. For example, two of the three major domestic automakers invested nearly $12 billion in research and development from 2009-2010, while parts and specialty manufacturers added another $3 billion. Heavy-duty diesel engine and equipment makers similarly made significant research investments exceeding $3.5 billion in 2009-2010 for five companies.8

FEDERAL R&D ACTIVITIES

A study by the U.S. Department of Energy (DOE) found public R&D investment in fuel economy technologies for heavy-duty trucks returned large benefits. “The federal return on investment is greater than 60 to one ($7.7 billion in fuel savings from $125 million in research funding) for technologies developed from federal research between 1999 and 2007 (benefits
The study projects that federal research efforts can save as much as 4.5 billion barrels of oil.


The 21st Century Truck Partnership (21 CTP) was the first phase in collaboration between federal agencies and heavy-duty truck, bus and hybrid power train manufacturers. The DOE established a partnership program between government and industry in 2000 with the goal of developing technologies that help transport a larger volume of passengers and goods at reduced emission levels while lowering dependency on foreign oil. The Department of Defense is also a partner in the efforts. The Partnership supported research, development and demonstration activities to achieve these goals with commercially viable products and systems.

Specific technology goals have been defined in five critical areas that will reduce fuel usage and emissions while increasing heavy vehicle safety. Objectives include an engine system demonstration of 50 percent or greater brake thermal efficiency in a test cell for a diesel-power Class 8 truck traveling 65 mph; a tractor-trailer vehicle demonstration of 50 percent or greater freight efficiency improvement; and a tractor-trailer 68 percent freight efficiency improvement over a 24-hour duty cycle. Teams are also researching technologies that will achieve a 55 percent stretch thermal efficiency goal in prototype engine systems by 2013. To date, the partnership has identified fuel formulations optimized for use in advanced combustion engines, and has obtained 45 percent thermal efficiency in trucks while meeting 2010 federal regulations.

This public-private partnership creates an incubator space for researchers to access national laboratories and universities and their technological expertise. Five teams of technical experts, with diverse government, business and academic backgrounds, are working together to develop new heavy vehicle engineering technology. The teams are focusing on engine idle reduction, hybrids, safety, engines and parasitic loss. The team that works on idle reduction, for example, investigates how engine subsystems might better enable the electrification of truck accessories, as well as how to integrate idle reduction components into vehicles. The team that works on parasitic losses is developing technologies for reductions in aerodynamic drag, accessory load and weight. The Partnership is also investigating issues related to energy-efficiency, modifying the definition of fuel efficiency to focus on “ton-mile of payload transported” as a measure of productivity.

The SuperTruck program builds upon the progress in reducing energy consumption from commercial vehicles from the 21 CTP and has funded several specific partnership projects with heavy-duty truck manufacturers. A significant portion of the SuperTruck program funds came from through the American Recovery and Reinvestment Act of 2009. Other parts of the program are funded through the six sub-programs of DOE’s.

**DOE VEHICLES TECHNOLOGY PROGRAMS & FUNDING**

The DOE Vehicles Technology Programs aim to reduce transportation emissions. These programs have delivered substantial energy savings, a reduction of 17.6 billion gallons of diesel fuel from 1995-2007 (approximately one percent of total crude imports).10

- The **Fuels Technology** program funds research for fuels and lubricants that can offer cost-competitive, cleaner alternatives to standard fuels. The program focuses on both petroleum-based fuels and non-petroleum fuels. The Advanced Petroleum-Based Fuels Diesel Emission Control Project, for example, is working to identify the best combinations of low-sulfur diesel fuels, lubricants, diesel engines and emission control systems to reduce emissions.

- The **Hybrid and Vehicles Systems** program provides funding to improve vehicle efficiencies and the overall integration of technologies at the systems level. For example, research funded under the program includes the development of heavy hybrid propulsion technologies, and the reduction of parasitic losses from heavy vehicle systems.

- The **Energy Storage** program funds research to develop durable and affordable advanced batteries, to be integrated into light- and heavy-duty vehicles. The battery technology developed within this program is conducive to start/stop, full-power hybrid electric, electric and fuel cell vehicles.

- The **Power Electronics and Electrical Machines (PEEM)** program provides funding for the development of PEEM technology in hybrid, plug-in hybrid, fuel cell and pure electric vehicles.
• The Advanced Combustion Engine (ACE R&D) program investigates ways to improve internal combustion engine and thermal efficiency in light, medium, and heavy-duty vehicles. The DOE Combustion Research Facility (CRF) collaborates on its research. Areas of focus include laser diagnostic and optical engine technologies, combustion modeling, emission control technologies and solid state energy conversion.

• The Materials Technologies program funds research for the potential uses of advanced materials – such as metals, polymers, composites and intermetallic compounds – in light- and heavy-duty vehicles. The program’s goal is to reduce vehicle weight through the development of propulsion materials and enabling technologies.

DOE also channels funding for diesel technology development through a variety of programs including the Small Business Innovations Research (SBIR) and Small Business Technology Transfer (STTR) programs. DOE’s Office of Energy Efficiency and Renewable Energy also provides direct funding to state energy agencies through the State Energy Program (SEP) and the Office of Industrial Technologies’ Invention and Innovation Program provides up to $250,000 in grants for the development of innovative concepts related to energy technology improvement.

VOLUNTARY DIESEL MODERNIZING AND UPGRADING (“RETROFIT”) PROGRAMS

One of the valued attributes of diesel engines and equipment is durability and longevity. Economic conditions in recent years have led to a delayed acquisition of new engines, machines and vehicles equipped with low-emissions technology, further extending the replacement cycles of equipment and resulting in an aging fleet population with overall higher emissions. As states look for strategies to reduce emissions and to meet National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter, the population of existing engines and equipment is of increasing interest. EPA has estimated the population of older diesel engines and equipment to be on the order of 20 million units.11

Given the substantial progress in environmental performance of current generation diesel emissions control technology and the availability of cleaner diesel fuels, there are opportunities to apply some of these emissions and technology solutions to the population of existing engines and vehicles, known as retrofitting.

To date, voluntary diesel retrofit programs have demonstrated remarkable societal benefits. One study of California’s Carl Moyer Program found a benefit-cost ratio ranging from nine to one to 16 to one.12 The Environmental Defense Fund estimated that a $600 million to $1.6 billion investment would yield $10 to $19 billion in health benefits nationwide.13 Similarly, the U.S. EPA determined that for every one dollar invested in diesel retrofit programs, as many as $13 dollars are returned in environmental and public health benefits.14

FEDERAL FUNDING PROGRAMS

From 2005-2011, federal funds have been invested in diesel engine retrofits. Typically administered by state and regional environmental and transportation agencies, these funds have come from three primary sources:

• The U.S. EPA’s Diesel Emission Reduction Act (DERA),

• The Department of Transportation’s Congestion Mitigation and Air Quality Improvement Program (CMAQ), and

• The U.S. Department of Agriculture’s Environmental Quality Incentives Program

DIESEL EMISSION REDUCTION ACT

Modernizing and upgrading existing diesel engines has been identified as a national priority since 2000. Much of this initial interest in retrofits focused on school buses, leading to the creation of U.S. EPA’s Clean School Bus USA program in 2003. Subsequently the Diesel Emissions Reduction Act was enacted as part of the Energy Policy Act of 2005, envisioning up to $1 billion between fiscal years (FY) 2006 and 2010 for grants and loans to support the installation of retrofits on heavy-duty diesel vehicles.

During its first five years, DERA received $519.2 million, $300 million of which came through the American Recovery and Reinvestment Act (ARRA) of 2009. Over the last several years,
funding requests have been approximately five times higher than the amount available, with roughly only one quarter of all applicants receiving program assistance. U.S. EPA estimates that more than $1 billion in qualified, unfunded project proposals have been received. For every dollar invested in the program, as many as three dollars are invested by other government agencies, private organizations, industry and non-profit organizations. According to U.S. EPA’s report to Congress on the program’s first year, the projects funded with the first $50 million will generate $580 to $1,600 million in societal benefits, and additional fuel savings of 3.2 million gallons in private benefits.\textsuperscript{15}

The U.S. EPA has invested DERA funds in four programs, as follows:

- The National Funding Assistance Program awards competitive grants to projects that implement certified diesel emission reduction technologies. Matching funds are provided by participants, generating $1.30 for every federal dollar invested.
- The Emerging Technologies Program supports innovative technologies which reduce heavy-duty diesel engine emissions.
- The SmartWay Finance Program issues competitive grants to establish national low-cost revolving loans or other financing programs to encourage adoption of advanced diesel technologies.
- The State Clean Diesel Grant Program provides funding to states to implement grant and loan programs for clean diesel projects.

In 2011, Congress reauthorized the DERA program for another five years from FY2012 – FY2016, but limited the authorized maximum funding level to $500 million over the five years rather than the initial $1 billion.

**CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT PROGRAM**

The Congestion Mitigation and Air Quality (CMAQ) program, established in 1991, funds transportation projects and other efforts that contribute to air quality improvements and reduce traffic congestion. CMAQ is jointly administered by the Federal Highway Administration and the Federal Transit Administration. In 2005 Congress identified diesel retrofits as a funding priority under the CMAQ program as part of the Safe, Accountable, Flexible, Efficient, Transportation Equity (SAFETE) Act. In the end, each state has discretion over its CMAQ dollars, and although some states have supported retrofit projects with these funds, they still represent an extremely small percentage of overall program expenditures.

**ENVIRONMENTAL QUALITY INCENTIVES PROGRAM**

The Department of Agriculture’s Environmental Quality Incentives Program (EQIP) was created in 1997 as a voluntary program to promote the compatible goals of agricultural production and environmental quality. EQIP funds a variety of environmental projects, of which air quality accounted for only four percent of the total from 2002-2008. However under the 2008 Farm Bill a new Air Quality Initiative was adopted under EQIP’s Conservation Innovation Grants Program which provided $37.5 million annually for a competitive grant program for projects in PM and NOx non-attainment counties. Diesel retrofits remain only one of several such projects, some changes in project ranking and conservation practice standards within the agency are expected to boost their numbers.

EQIP funds are allocated to state conservationists, who with state technical committees, decide how funds will be allocated. California has led the way in using EQIP funds for retrofitting agricultural equipment, particularly in the San Joaquin Valley.

**STATE AND LOCAL FUNDING PROGRAMS**

Several states fund research into low-emitting diesel technologies as well as managing retrofit programs. The U.S. EPA assists collaborative multi-state programs as well, such as the five regional Diesel Collaboratives, and the Midwest Diesel Initiative.\textsuperscript{16}

California leads the country in state-funded diesel retrofit and technology programs. The Carl Moyer Memorial Air Quality Standards Attainment Program is a voluntary incentive-based grant program to reduce emissions through retrofitting diesel vehicles and equipment. The program is funded at approximately $140 million per year. In its first 12 years, the program has provided over $680 million in state and local funds to clean up approximately 24,000 engines.
Cumulatively, this has reduced NOx emissions by about 100,000 tons and diesel PM by about 6,000 tons.

The two other primary funding sources in the state have been Proposition 1B and AB118. A summary of programs operating with these funds are summarized below. Most retrofit funds are administered by the California Air Resources Board, but are distributed through California’s air districts, which have considerable discretion over funding priorities.

Texas has the second largest state-funded diesel grant program, the Texas Emissions Reduction Plan (TERP), modeled after CARB’s program and administered by the Texas Commission on Environmental Quality (TCEQ). The program is funded primarily through vehicle title application fees, but surcharges on new heavy-duty diesel vehicles and equipment sales and truck inspection fees also contribute. TERP awarded approximately $800 million in grants between 2001 and 2008.

Outside of California and Texas, few states have dedicated state funding to support diesel retrofit programs. Ohio and North Carolina have established programs, but they are much smaller and have not been consistently funded. They, like all other states, depend on DERA and CMAQ monies to assist their state-run diesel retrofit programs. New York’s Department of Transportation receives funds from DERA and CMAQ, and subsidizes diesel programs through its New York 1996 Clean Water/Clean Air Bond Act, under which $175 million has been distributed. State and local governments also administer tax exemptions, deductions and credits for diesel upgrades, along with low-interest loans for purchasing alternative fuel vehicles. Georgia and Oregon, for example, offer tax incentives that encourage diesel retrofits; many states offer incentives for idle reduction and fuel-efficiency technology. Biodiesel tax incentives are a popular means of funding alternative fuels, available in almost all states.

**CALIFORNIA EFFORTS**

California provides three main funding sources for diesel engine replacement and diesel technology research:

- **The Carl Moyer program** – established in 1998, and principally funded by general fund, vehicle registration fee, and tire fee revenues – provides grants to retrofit on-road, off-road, marine, and locomotive engines and equipment, as a means to lower polluting air emissions. Assembly Bill 923, approved in 2004, expanded the Carl Moyer program to include retrofits for cars and light-duty trucks, as well as agricultural sources of air pollution and hydrocarbon and particulate matter emissions. Under the law, additional funding for the Moyer Program is provided from tire fee revenues, and local air districts are authorized to increase motor vehicle registration fees by up to $2 to pay for pollution reducing programs.

- **Proposition 1B,** also known as the Goods Movement Emission Reduction Program, was a 2007 voter-approved ballot initiative geared toward reducing polluting air emissions and lowering public health risks associated with freight movement along California’s transportation corridors. Eligible projects under the initiative include retrofitting diesel truck engines, installing electrical infrastructure on cargo ships, and replacing locomotive and commercial harbor craft engines.

- **AB 118,** which passed in 2007, consists of three programs – financed by smog abatement, vehicle registration, and vessel registration fee revenues – which fund air quality improvement projects and alternative and renewable fuel development, including clean diesel technology:
  - **Air Quality Improvement Program** provides grants to fund clean vehicle and equipment projects which reduce criteria and toxic air pollutants, as well as research on the air quality impacts of alternative fuels and advanced technology vehicles.
  - **Enhanced Fleet Modernization Program,** also known as the Car Scrap program, funds the voluntary retirement of high-emitting passenger cars and light- and medium-duty trucks. The program is administered by the Bureau of Automotive Repair.
  - **Alternative and Renewable Fuel and Vehicle Technology Program** provides grants, revolving loans, and loan guarantees to develop and deploy innovative technologies, as administered by the California Energy Commission.
Table 6: Past California Funding for Diesel Retrofits and Emerging Technology ($ Millions; Fiscal Years)

<table>
<thead>
<tr>
<th>FUNDING SOURCE</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011 (ESTIMATED)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carl Moyer</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>AB923</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Prop1B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>250</td>
<td>200</td>
<td>275</td>
<td>210</td>
</tr>
<tr>
<td>AB118</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>AQIP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Car Scrap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Alt. Fuel</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>

Table 7: Estimated Future California Funding for Diesel Retrofits and Emerging Technology* ($ Millions; Fiscal Years)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carl Moyer</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>AB923</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Prop1B</td>
<td>250</td>
<td>Remainder of 250</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AB118</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>-</td>
</tr>
<tr>
<td>AQIP</td>
<td>30**</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>Car Scrap</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>Alt. Fuel</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>-</td>
</tr>
</tbody>
</table>

*Projections, in today’s dollars, with actuals dependent on bond sales.
REFERENCES

1 California Air Resources Board, Assembly Bill 32: Global Warming Solutions Act, http://www.arb.ca.gov/cc/ab32/ab32.htm


6 Memorandum from the Los Angeles County Metropolitan Transportation Authority to Executive Management and Audit, Construction, and Ad Hoc Sustainability and Climate Change Committees, March 17, 2011


8 Aspen Environmental Group, 2011, Review of annual reports


15 Ibid

Diesel technology supports a wide array of economic activities. Producing the inputs to diesel technology also creates economic activity. Oil extraction, fuel refining, engine and vehicle manufacturing, and equipment servicing all require hiring employees and purchasing commodities and services. Further, the use of diesel in trucks, trains and ships facilitates the connections between factories, warehouses and stores. All of these activities can be translated into expenditures of dollars and jobs created. Economic models have been developed to assess how these expenditures and jobs influence the economy as a whole.

**THE CONCEPT OF TOTAL OUTPUT, VALUE ADDED AND GROSS DOMESTIC PRODUCT**

Diesel technology’s significance to the U.S. economy can be assessed using an input-output model based on the IMPLAN system of regional economic accounts. The IMPLAN data set is derived from U.S. Bureau of Economic Analysis data. The IMPLAN model assesses impacts to such variables as industry output (or gross sales), labor income (employee compensation and self-employed proprietors’ earnings), other property ownership-related income (corporate profits, dividends, rents and other returns on capital assets), indirect business taxes (mainly sales and property taxes), and employment (full- and part-time jobs).

In general economic activity is measured using two important concepts. The first is total output. This is the total expenditures and receipts associated with all transactions in the economy. However, it includes both activity which may only be a simple transfer with little associated economic production, and the actual economic activity that is facilitated by or facilitates the transfer. The second concept, value added, measures the actual economic activity associated with a transfer, and is a component of total output. It is the component that adds actual wealth to the economy. Value added is the economic value added to a product by an industry beyond the costs of purchasing the necessary inputs from other industries, as measured by labor and property income and indirect taxes. Each step of the production, delivery and service process adds incremental value. The cumulative value added across these industries, plus any out of state imports, equals the total cost to provide the final product to the end consumer. The sum of all of this value added is known as the **Gross Domestic Product** or GDP. The GDP excludes out of state imports and does not include the multiplier effect. Changes in the GDP are followed closely in the business and economic press.

**VALUE ADDED AND THE GDP, INPUT-OUTPUT MODELING – BRIEFLY**

IMPLAN data provides the basis to construct a system of inter-industry transaction accounts and an associated social accounts matrix (SAM) to trace the economic relationships among industries, and track transfers of income among institutions (i.e., households, enterprises and governments). The key feature of the IMPLAN system (and other input-output models, such as RIMS) is its system of multipliers that translates initial changes in an industry’s output or final demand for its products into values reflecting the recirculation of income and spending through the economy. The process of recirculation results in a multiple expansion (or contraction, in the case of a decline in output or demand) of earnings, output and employment that is the result of households and other economic units changing spending due to the “stimulus” of the initial change in output or demand. Simply put, the *multiplier effect* captures how spending

---

a IMPLAN® (Impact PLANning) is a proprietary software product of the Minnesota IMPLAN Group, Inc., of Stillwater, MN.

b IMPLAN is one of several regional economic impact models used to assess economic changes in local, state and national economies. Other such models include RIMS, REMI, and DRAM.
one dollar may multiply into two or three dollars of increased economic activity throughout a state or nation.

The IMPLAN model’s multipliers apply to such variables as industry output (or gross sales), labor income (i.e., employee compensation and self-employed proprietors’ earnings), other property ownership-related income (i.e., corporate profits, dividends, rents and other returns on capital assets), indirect business taxes (mainly sales and property taxes), and employment (full- and part-time jobs). The labor and property income and indirect tax variables together comprise the concept of *value added*, which represents the activity’s contribution to regional, state, and national gross product—the usual measure of the value of all new goods and services produced in a year.

The multiplier process traces three stages of effects through an economy: direct, indirect, and induced.

- The direct effect is the initial change in an industry’s output or demand for its product (commodity or service). It involves the factors of production – employees, property, and other resources – directly producing the initial good or service.

- The indirect effect involves the suppliers of goods and services to the sectors that are realizing the direct effect or initial change, as the latter sectors replace their inventories drawn down by sales to the initial direct effect industry.

Finally, the induced effect involves the economic institutions and industries receiving expenditures by households and other institutions earning income at the direct and indirect stages. Spending on consumer goods and services out of the wages, salaries and other earnings of the direct and indirect stage factors of production circulates and recirculates through the economy until it is dissipated through leakages in the form of savings and payments for goods and services from outside the local economy. All told, the cumulative changes in income and employment are a multiple of the initial direct effect.⁴

The system of multipliers makes it possible to estimate the values of income and employment throughout the economy that are supported, directly and indirectly, by a given industry’s outlays for labor, capital, and inputs of goods (e.g., diesel fuel) and services. For example, if Industry X produces and sells $100 million worth of goods and services in a year and, per the IMPLAN model, that industry’s total output multiplier is 2.50, then the indirect and induced economic activity supported by industry X’s $100 million of direct output would be worth another $150 million, for a total contribution to gross output of $250 million. Similar multipliers are provided for the other parameters of economic activity, namely value added (i.e., labor income, other property income and indirect business taxes), and employment. These multipliers, in conjunction with the model’s database of inputs consumed by industry sectors (their intermediate inputs) in the process of producing their final products, also enable analysts to calculate the fractional value of economic effects that can be associated with utilization of a given input (e.g., diesel fuel).

**DIESEL INDUSTRY PROPORTIONAL INFLUENCE MEASUREMENTS**

The proportion of NAICS industry sectors utilizing diesel fuel or diesel technologies was determined using a two-step process. Industry data available in the literature and from government agencies and trade organizations provided diesel percentages for a variety of sectors. These data were then input into a set of calculations based on IMPLAN relationship matrices to determine sector percentages. The following describes the methodology used to distinguish diesel and non-diesel components within industry sectors.

⁴ The IMPLAN multipliers are the so-called “Type SAM” (social accounting matrix) multipliers which take account not only of Leontief inter-industry transactions (the Type I multiplier between the direct and indirect stages) and household income and expenditures (commonly referred to as Type II multipliers, which encompass the induced stage), but also for inter-institutional transfers among households and other institutions, including such transfers as Social Security payments and receipts, income tax payments, and earnings outflows to non-residents. Accounting for the inter-institutional transfers permits the analysis of induced effects to be confined to households’ consumption spending of disposable income after netting out savings and tax payments, thus reducing potential over-estimation of the total multiplier effect.
INDUSTRY DATA AVAILABLE IN LITERATURE

Diesel Technology and the American Economy, prepared by Charles River Associates in 2000 for DTF, provided the methodology for initial identification and calculation of diesel percentages for Internal Combustion Engines, Farm Machinery and Equipment, Construction Machinery, Mining Machinery and Mineral Processing Equipment, Motors and Generators, and Pumps and Compressors. Data for materials handling equipment, such as cranes, lifts, and hoists, was included as a subset of Construction Machinery. For each of these categories, the most recent U.S. Census Bureau Current Industrial Report (CIR) data was used to differentiate the proportion of each industry using diesel. While 2009 data was available for Farm Machinery and Equipment, Construction Machinery, and Mining Machinery and Mineral Processing Equipment, the most recent CIR data for Internal Combustion Engines and Motors and Generators was from 2003. In each set of data, the diesel percentage was determined by identifying the production value of diesel-fueled power sources or self-propelled equipment and comparing it to the total production value.

Vehicular fuel use was derived from the U.S. Department of Energy and DTF study data. The 2010 Transportation Energy Data Book: Edition 29 provided data to calculate diesel percentages for heavy-duty trucks, ships and public transit (including both bus and rail) by listing fuel types and uses in each sector. Diesel percentages for automobiles and light-duty trucks were calculated from 2010 numbers of vehicles in operation, as provided by DTF. The diesel percentage of petroleum refining was determined from 2009 U.S. Energy Information Administration data on refined petroleum sales. The diesel percentage for pumps and compressors was determined using 2007 Census of Agriculture data, which reports pumping by fuel type. Finally, the diesel percentage for military armored vehicles, tanks and tank components was assumed to be 100 percent, based on the 1990 implementation of the Department of Defense single-fuel concept, which requires U.S. forces to use only one fuel while deployed.

IMPLAN RELATIONSHIP MATRICES

National data in IMPLAN provided each industrial sector with a listing of the inputs used by the sector in production of its commodity, along with the value of those inputs. Sectors such as manufacturing, agriculture, and residential and non-residential construction required aggregating many individual NAICS sectors together to simplify the calculation process. Using the diesel percentages described above, the value of each commodity’s inputs attributable to diesel was determined. In the case of some sectors, diesel percentages were extrapolated from the basic percentages described above. The diesel percentage for many inputs, however, required the overall diesel percentage for another sector or, recursively, from its own diesel percentage. These calculations were linked and solved as a matrix to provide the final diesel percentage for each industrial sector.

---

While the M1 Abrams tank runs a gas turbine on JP8, the total fuel use for these tanks is a very small percentage of total U.S. Army fuel use. We do not have data available on the specific fuel use for these vehicles.