A Preliminary Assessment of the Gaseous Fuels Aftermarket Conversion Industry

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INTRODUCTION

Alternative transportation fuels like compressed natural gas, propane, electricity, and methanol, are increasingly considered viable options to traditional transportation fuels such as gasoline and diesel. There are an estimated 425,000 liquified petroleum gas (LPG) vehicles and 30,000 compressed natural gas (CNG) vehicles in use in the US today. Advantages of these alternative fuels include that they are cleaner burning, are less expensive than gasoline per gallon equivalent, and can reduce vehicle maintenance. However, with few exceptions such as the Ford CNG Crown Victoria and the GMC Sierra, one currently cannot purchase alternative fuel vehicles (AFVs) from automakers. Nearly all of the AFVs on the road today were retrofitted to enable them to run on fuels other than gasoline or diesel. This report characterizes the industry that performs these retrofits, the aftermarket conversion industry.

Historically, the aftermarket conversion industry has been driven by economic factors. The number of conversions fluctuated directly with the price of gasoline. Conversions were done on a one-by-one basis. Conversion kits containing all the necessary components to convert a vehicle were frequently "one-size-fits-all" and employed rudimentary technology. In the past few years, however, the outlook for the conversion industry has changed dramatically as a result of the 1990 Clean Air Act Amendments (CAA), state legislation (especially in California, Texas, Oklahoma, and Colorado), and other state and local initiatives that promote alternative fuels. Conservative estimates by the gaseous fuels industry indicate that there will be at least 4.5 million AFVs on US roads by the year 2005.

To meet the demand for AFVs, the aftermarket conversion industry is undergoing a rapid transition: Many new companies are entering the industry; technology is becoming increasingly sophisticated; original equipment manufacturers (OEMs - e.g., automakers) are entering the market; and companies are facing significant learning curves. As demand for AFVs grows, large companies may experience substantial economies of scale.

The purpose of this report is to provide information to be used in assessing the potential impacts of EPA's proposed Gaseous Fuels and Clean Fuel Fleet rulemakings on the aftermarket conversion industry. Therefore, the report will focus on issues germane to determining these impacts (such as financial profiles of companies involved, future trends in industry development and sales, and costs of complying with conversion requirements) rather than assessing the viability of current technologies or the emissions benefits of alternative fuels. Moreover, the report focuses on conversions to CNG and LPG as conversions to these fuels are most viable at this time, even though EPA's proposed conversion regulations could potentially apply to any fuel (e.g., liquid natural gas).

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1 NPGA and U.S. Department of Energy, cited by LP Gas Clean Fuels Coalition.

2 Energy Analysis, American Gas Association Planning and Analysis Group, Appendix 1, January 1991.

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This report is divided into six chapters. Chapter 1 presents the methodology ICF used to gather information and develop representative model companies for the three major industry segments (kit manufacturers, engineered converters, and installers). Chapter 2 provides an overview of the industry and discusses factors relevant to assessing impacts such as the industry structure and nature of competition. Chapter 3 provides information on the major industry segments and presents model companies in each segment. Chapter 4 summarizes the cost structure of the aftermarket conversion industry. Chapter 5 discusses demand for conversions. Finally, Chapter 6 provides a brief discussion of some aspects of the potential impacts of the regulation of gaseous fuels and clean fuel fleet conversions.
CHAPTER 1
METHODOLOGY

There are no publicly available, comprehensive reports on the US aftermarket conversion industry nor even a complete list of participating companies. This chapter explains the methodology and data sources used to characterize the aftermarket conversion industry. It is presented in four sections: Identification of Participating Companies and Collection of Industry Information; Collection of Company-Specific Information; Development of Representative Model Companies; and Limitations of the Data.

1.1 Identification of Participating Companies and Collection of Industry Information

A two-pronged approach was used to generate a list of companies participating in the conversion industry and to gather general industry information on trends and business practices. First, ICF compiled an initial listing and partial characterization of firms involved in manufacturing, assembling, installing, and/or distributing CNG and LPG conversion kits. Second, ICF contacted industry organizations, national information sources, and state representatives. Using this approach, ICF generated a list of companies in the conversion industry and additional state and industry representatives who could provide general information on the industry.

ICF then contacted these various organizations to obtain general information about the industry, lists of participating companies, and recommendations of additional information sources until it began to get repetitive recommendations. The organizations ICF contacted are listed in Exhibit 1-1.

Due to the limitations of the Paperwork Reduction Act, ICF spoke with only one or two representatives of conversion kit manufacturers, engineered converters, and installers to obtain public information about their companies and general industry and market information. ICF's questions and the content of its conversations with each of these industry representatives varied greatly because of the differences among companies and company types.

Even though contacts with industry participants were limited, ICF is confident that this thorough approach has allowed it to identify the majority of companies participating in the aftermarket conversions industry and to develop a sound industry characterization. It is unlikely, however, that ICF has identified all small and recent start-up companies as many continue to enter the industry or all companies that have converted parts of their fleets on a trial basis.
EXHIBIT 1-1

ORGANIZATIONS CONTACTED

- American Gas Association
- Automotive Industry Action Group
- California Air Resources Board
- Clean Air Texas
- Colorado Dept. of Health
- Engine Manufacturers Association
- Interstate Natural Gas Association
- LP/Gas Magazine
- LPG Coalition
- National Highway Traffic Safety Administration
- National Fire Protection Association
- National Renewable Energy Labs
- National Research Council Transportation Board
- National Gas Transportation Association
- National Propane Gas Association
- Natural Gas Vehicle Coalition
- Natural Gas Supply Association
- Natural Gas Fuels Magazine
- Oklahoma Alternative Fuels Program
- Society of Automotive Engineers
- Texas Railroad Commission
- Texas Air Control Board
- Texas General Land Office

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1.2 Collection of Company-Specific Information

Once ICF identified the majority of companies in the industry, it gathered publicly available information on individual companies. Sources of data included Dunn & Bradstreet's Business Information Reports, Market Identifiers, Electronic Business Directory, and Financial Records Plus; and Trinet's US Businesses and Company Database.

ICF used information from these sources and industry contacts to create a company database with selected information:

- Company name;
- Location;
- Contact person;
- Corporate status;
- Name of parent company (if relevant);
- Four digit Standard Industrial Classification (SIC) codes corresponding to the principal business activities;
- Activity or activities performed in the industry - manufacture component(s) or entire kit, distribute components/kits, perform conversions, type of conversions (CNG or LPG);
- Number of conversions performed in the past year, past 5 years;\(^3\)
- Indication of whether the financial information presented pertains to the parent company or affiliate/division/subsidiary/joint venture;
- Financial information for the most recent fiscal year - Annual revenues (sales)
  - Net worth
  - Current assets
  - Current liabilities
  - Current ratio
  - Working capital
  - Net profit (income)
- Total assets
  - Estimated percent of income from conversion activities
  - Financial condition (fair, good, strong, unbalanced)
  - Trend (in sales, general financial stability);
- Whether the company is located in a state with a centralized or decentralized inspection and maintenance program (a proxy for accessibility of state emission inspection facilities); and
- Whether the company is located in one of the 22 non-attainment areas.

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\(^3\) This information was available for only a small minority of companies.
1.3 Development of Representative Model Companies

To accurately characterize firms participating in the aftermarket conversion industry, ICF developed a set of model firms for each of the three segments of the industry: kit manufacturers, engineered converters, and installers. Each set consisted of a model company profile for the typical (median) large firm, typical (median) small firm, and lower quartile small firm in the segment. The process by which ICF developed these model firms is presented below.

Identification of Large and Small Companies

To develop model firms, ICF first categorized each identified firm as small or large. As specified in the Regulatory Flexibility Act, ICF used Small Business Administration (SBA) definitions of small firms to make an initial determination of small and large entities within each segment. The SBA size cutoffs are typically at 100, 500, or 750 employees, depending on the industry as defined by the four-digit SIC codes. Among the 60 firms identified as participating in the aftermarket conversion industry, 43 four-digit SIC codes (most of which have SBA cutoffs of 100 employees) are represented. This variety reflects the fact that the industry is new, diverse, and changing.

To judge whether this initial determination was correct, ICF checked if the companies known to be major players (e.g., IMPCO, ANGI) in the industry were large firms. This was done because the primary purpose of a regulatory flexibility analysis is to detect disproportionate impacts of regulations on small companies relative to large companies in the affected industry segment (which may not be the industry represented by the company’s SIC code). In most cases, the initial determination seemed correct. However, a few small firms that had close to the cutoff number of employees and are considered major players in the industry were classified as large firms for the purpose of this analysis.

Interpolating for Missing Data

Second, ICF utilized data from companies with complete financial information to interpolate financial information that was missing for other companies in the same segment and size category. For many of the smaller firms, for example, only information on SIC code, employees, and sales was publicly available. To estimate other financial information needed to develop representative model companies, ICF used regression analyses to identify relationships among various characteristics. For example, because relationships between sales and employees, and assets and employees, were generally very strong, missing values could be filled in with a reasonable degree of confidence. Filling in missing data on return on assets was more difficult, in part because profits tend to be more volatile and subject to special factors (such as start-up costs and write-off). For firms for which data on profits were unavailable, ICF assumed that the firm’s return on assets was equal to the average profit for its size category. ICF also tested whether rates of profit among small firms are related to size, but was unable to confirm this hypothesis.
Determining Characteristics of Model Companies

ICF’s third step in developing model firms involved determining the actual characteristics (e.g., number of employees, sales, assets, profits) of each model firm. This was accomplished by separately sorting employment, sales, assets, and profits by magnitude for small and large firms in each industry segment. Then, the initial characteristics for the large model firms were chosen using the median employment, sales, assets, and profits for the large firms. Similarly, the initial characteristics of the two smaller model firms were selected using the median and lower quartile values from the employment, sales, asset, and profit distributions of small firms in each segment. To make the model companies internally consistent, other characteristics (e.g., return on assets) were calculated from the initial model firm characteristics.

By using this approach, the nine model firms (three for each of three segments) are as representative as possible (given the data and time restraints) of actual firms’ characteristics that are most relevant for projecting regulatory impacts. The creation of three models of different sizes for each segment allows for the comparison of impacts on large and small entities.

1.4 Estimating Potential Compliance Costs

ICF assessed the potential impacts of the proposed regulations by comparing compliance costs to the revenues and profits in each model firm profile. The model firm approach, as opposed to a direct assessment of impacts on each of the actual firms, was chosen in response to data limitations and the inherent difficulties of projecting how specific firms will grow and change in a rapidly developing industry.

To assess the impacts of regulatory costs using the model firms, ICF estimated the magnitude of each regulatory cost element for each type and size of firm. Costs that cannot be easily passed on to customers were compared to the assets and profits of the model firm of the appropriate type and size; costs that will probably be passed on to customers were compared to the model firm’s sales, to determine whether a price increase large enough to cover the cost increase would be large enough in percentage terms to affect sales significantly.

1.5 Limitations of the Data

As a preliminary assessment of a new industry, this report is necessarily based on data that are limited in significant ways. The limitations stem from lack of publicly available information about industry participants, the methodology selected to accommodate data inadequacies, and the inherent difficulties of projecting the characteristics of a changing industry into the future.

Since the aftermarket conversions industry is relatively new and small, there are no comprehensive sources of information available on the industry. Large classes of valuable information, such as the number of kits sold per company, the type of technology used in
each company's products, and the distribution of sales between light-duty and heavy-duty vehicles, are neither tracked through a federal data collection effort nor otherwise publicly available. Moreover, the ability to obtain data from companies directly was limited by the Paperwork Reduction Act; even when contacts were made, many firms justifiably withheld information they judged proprietary.

Even if complete information had been available on the industry as it now stands, considerable uncertainty would remain regarding the industry's characteristics over the next decade and beyond. This is a new industry, which is changing technologically and structurally; the driving factor behind demand for the industry's products is in the process of shifting from economic advantages to an emphasis on emissions reductions; and many new companies are appearing each year. There is regulatory uncertainty in predicting when state implementation plans (SIPs) will go into effect and what they will entail (e.g., Texas emphasizes CNG, and does not consider reformulated gasoline an alternative fuel). Finally, it is not clear how clean fuel vehicles will be distributed across all alternative fuels, and between conversions and OEMs. Thus, no solid estimates are available even of the total number of conversions per year in the future, and it is even more difficult to predict sales for individual firms, regions, and types of vehicles (such as heavy vs. light duty vehicles). Nevertheless, ICF used appropriate analytical and modeling techniques, plus information obtained from EPA and others, to make the best possible projections for the future for the three market segments and parameters of interest.
CHAPTER 2
INDUSTRY OVERVIEW

In 1995, there are projected to be 45,000 clean fuel fleet vehicles (CFFVs) in the US.\(^4\) This number is expected to increase to 105,000 by 1998 and to 1.2 million by 2010.\(^5\) Approximately one-quarter of these vehicles are expected to use either CNG or LPG.\(^6\) This demand for CFFVs will come about as a result of a number of Federal, state, and local mandatory and incentive programs. In addition, there will be a few hundred thousand other vehicles converted to use gaseous fuels as a result of the fuel cost-savings associated with CNG and LPG. This growth will bring about dramatic technological, structural, and competitive changes in the aftermarket conversion industry. This chapter first provides a brief summary of the history of the US aftermarket conversion industry. It then discusses current industry characteristics, the nature of competition, the industry structure, and how these factors are expected to change in the coming decade.

2.1 History

The aftermarket conversion industry first developed in Italy during and after World War II, when it became necessary to substitute domestic gas for unavailable oil. Aftermarket conversions to CNG and LPG have since become significant in a number of countries, including Argentina, Australia, Canada, Holland, Italy, New Zealand, and the US.

In the US, interest in LPG as a vehicle fuel was sparked by its low cost and by LPG marketing campaigns in the 1950s and 1960s; interest in LPG has continued through the present, increasing and decreasing with gasoline price movements. Because LPG has relatively few uses and is produced as a byproduct of petroleum refining and natural gas processing, supply chronically exceeds demand; this results in LPG having a relatively low price. Many retail LPG supply companies provide low-cost LPG conversions as a marketing tool to expand LPG demand and to smooth seasonal fluctuations. Customers for these conversions are primarily fleets of vehicles with engines designed for gasoline use such as city delivery trucks.

CNG has also been used as a vehicle fuel for some time in the US. Interest in CNG has tended to peak in times of rising oil prices and/or limited oil supply. The major advocates of CNG, and the major fleet users to date, have been the natural gas distribution companies.

\(^4\) Energy Analysis, American Gas Association Planning and Analysis Group, Appendix 1, January 1991.


\(^6\) Office of Mobile Sources Memorandum to ICF, Estimates of Gaseous Fuels OEMs and Conversions, July 9, 1992.

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These companies see the vehicular market as offering the potential for expansion (at a time when most of their other potential markets are already saturated), and as offering a useful counter-peaking demand profile (automotive fuel use tends to peak in the summer, while natural gas demand has a sharp winter peak for heating). Some gas utilities had established test fleets of natural gas vehicles (NGVs) in the 1960s, but interest waned with the increase in natural gas prices and limitations in gas use in the Natural Gas Policy Act passed in the late 1970s. Currently, the continuing low price of natural gas, the CAA emphasis on alternative fuels, and substantial funding for promotion and R&D of natural gas vehicles are combining to sustain interest in NGVs at a high level.

2.2 The Conversion Industry is both Emerging and Transitional

The aftermarket conversion industry is unusual in that it is both emerging - in terms of technology and growth - and transitional - it may well be largely supplanted by automakers' mass production of AFVs within 20 years or so. The following paragraphs describe general characteristics of the aftermarket conversion industry.7

Embryonic companies. Many new and small companies are entering the conversion industry, especially in the states such as Texas and Oklahoma that have alternative fuels legislation and CNG/LPG suppliers.

Technological uncertainty. Conversion technology is rapidly changing. For example, it is moving from mechanical to electronic controls and from open- to closed-looped fuel metering controls. There is a large degree of uncertainty about which systems or technologies will perform best and which companies will produce them.

Erratic product quality. There are few standards for conversion kits and no national accreditation of mechanics who perform conversions. Therefore, the quality of kits and installations to date has been erratic. Poor quality from a few firms could lead to image and credibility problems for the entire industry.

Image and credibility problems with the financial and insurance communities. Uncertainty about technology, demand, upcoming regulatory requirements, and mechanics' capabilities is creating some hesitancy in the financial and insurance communities. Several industry participants indicated that small companies are having difficulty obtaining adequate insurance for performing conversions. Insurance is necessary to allow companies to bid on state (and probably private) contracts for fleet conversions. New small companies may also have a hard time securing low-cost financing to purchase a dynamometer and other necessary equipment (e.g., computers) and pay for the training that some kit makers require before they allow a converter to use their kit.

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7 Many of these characteristics are common to emerging industries as described by Michael E. Porter in his book, "Competitive Strategy: Techniques for Analyzing Industries and Competitors."
Regulatory-driven. While the proposed Clean Fuel Fleet and Gaseous Fuels rulemakings do not mandate aftermarket conversions or the use of gaseous-fueled vehicles in general, they do require that conversions are performed with EPA-certified kits. The effect of this requirement is that each conversion kit technology be thoroughly tested and certified to assure it meets emissions standards. This process, unless managed correctly, may unduly slow product introduction.

Absence of infrastructure. The conversion industry historically has been subject to the "chicken and egg" syndrome. Fuel suppliers are unwilling to invest in an alternative fuel distribution system until they are assured that there will be a sufficient demand for the fuel; kit manufacturers and automakers are reluctant to invest in developing new and improved AFVs until they are assured there will be easily accessible fuel for their customers. The CAA, state legislation, and other initiatives have helped to resolve this impasse, at least in non-attainment areas.

Perceived likelihood of obsolescence. Potential buyers may be hesitant to convert their vehicles as they are aware technology is changing and fear that second- or third-generation technology will make obsolete currently available kits. This hesitancy is somewhat lessened for fleet owners by the fairly rapid turnover of fleet vehicles and by the institution of credit and incentive programs.

First-time buyers. Nearly all AFV purchasers in the next five to ten years will be first-time buyers. They will need to be convinced that a vehicle retrofitted to run on CNG or LPG is right for them. This will take considerable amounts of consumer education about the pros and cons of each alternative fuel and the technologies used to convert vehicles. This is particularly important for fleets as it will take a relatively large investment to convert the portions required by the CAA and to make the necessary changes in maintenance programs and mechanic training.

2.3 Nature of Competition

The aftermarket conversion industry is very competitive - and it is growing more so every year. Exhibit 2-1 depicts the competitive forces in the industry.\(^8\) It is the relative strength of these forces that will determine the long-term profit potential of the industry.

\(^8\) This competitive forces model was first presented by Michael E. Porter in his book, "Competitive Strategy: Techniques for Analyzing Industries and Competitors."
EXHIBIT 2-1
COMPETITIVE PRESSURES ON THE AFTERMARKET CONVERSIONS INDUSTRY

POTENTIAL ENTRANTS
- Fuel Suppliers
- High-tech Manufacturers

SUPPORTERS
- Component Manufacturers

INDUSTRY COMPETITORS
- Kit Makers
- Engineered Converters
- Installers

BUYERS
- Fleets
- Mass Market

SUBSTITUTES
- Reformulated Gasoline
- Conventional Vehicles
- Electric Vehicles
- OEM Vehicles

Significant Bargaining Power
High Threat of Entry
Rivalry Among Existing Firms
High Threat of Substitution

Significant Bargaining Power
Industry Competitors.

There are two main activities in the aftermarket conversion industry: 1) The design and manufacture of components necessary to convert a vehicle to run on a gaseous fuel; and 2) the actual conversion of the vehicle. For the purpose of this report, companies who primarily perform the first activity are called kit makers as they manufacture or assemble components into conversion kits. Companies who perform the second activity are called installers since they convert vehicles by installing conversion kits on vehicles, or assembling and installing the necessary components.

An example of a hybrid company that performs both activities is the engineered converter. These companies work closely with OEMs to develop and refine a conversion system for a specific vehicle type. They generally perform large numbers of conversions and participate in marketing the converted vehicles.

As the industry grows, the distinctions between these company types is fading. Kit makers are integrating vertically by opening conversion centers and/or developing a network of authorized installers. Engineered converters are packaging their conversion systems and selling them to others to install.

As a result, companies in the aftermarket conversion industry compete both within and across segments. For example, the larger kit makers compete with engineering start-ups in the kit maker segment. Larger kit makers also tend to be vertically integrated and thus compete (with price and knowledge advantages) with installers.

Currently, competition among and between kit makers and engineered converters (and potential entrants) is via product differentiation. The companies with technologies able to meet upcoming federal and state emissions standards, or optimize performance of AFVs, are expected to dominate the industry. Currently, this competition is primarily among domestic companies. However, competition is likely to become global as OEMs enter the market and companies involved in the conversion industry in other countries introduce their products to take advantage of the large demand for AFVs in the US.

Competition among kit installers is on a geographic and price basis. Buyers usually do not travel significant distances to have their vehicles converted. Conversion companies located in states with significant conversion activities (essentially Texas, Oklahoma, and Colorado) will gain an advantage over companies in other locations as they gain more experience and move along the learning curve.

For conversion companies within a given area and for diversified companies (which may have some cost carrying and competitive advantages), competition is on the basis of price. Fuel suppliers (who often offer conversions at cost because of expected future profits from fuel sales) and large conversion centers (who are able to purchase kits and other supplies in bulk) may have a price advantage over other companies. Profits for small installers are currently low or non-existent. Each of the three segments will be discussed in more detail in Chapter 3.
Potential entrants.

As expected in a transitional auto industry, hi-tech auto parts manufacturers have a high probability of entering the conversion industry. Suppliers of alternative fuels are expected to continue entering the industry, particularly into the conversion segment. They also are entering other segments by forming joint ventures with manufacturing or engineering firms.

Suppliers.

Manufacturers of components that are critical to a kit's ability to meet emissions standards (e.g., closed-loop carburetors) or increase performance (e.g., electronic fuel injectors) have considerable bargaining power.

Substitutes.

The gaseous fuel conversion industry faces substantial threats of substitution from OEMs producing gaseous-fueled vehicles. General Motors, Ford, and Chrysler all have recently introduced CNG vehicles. While the incremental cost of a retrofitted vehicle and a CNG OEM are roughly the same now, OEMs are expected to have a substantial price advantage due to mass production by the year 2000. The aftermarket conversion industry also faces competition from manufacturers or converters of vehicles using other types of alternative fuels. Threat of substitution of reformulated gasoline is particularly high as it requires no alteration of the vehicle.

Buyers.

Fleets have large bargaining power within the conversion industry since they offer the potential to convert large numbers of vehicles. To take advantage of potential cost-savings, larger fleets may have an engineered converter develop a demonstration vehicle and then train in-house mechanics to actually convert and maintain the fleet.

In addition to these forces, government is potentially a significant competitive force in the aftermarket conversion industry. Demand for AFVs is essentially being driven by the federal CAA and state legislation and initiatives. Emission standards are affecting technology and greatly increasing the amount of R&D on AFVs; they may also affect the relative feasibility, cost, and quality of substitutes. Regulatory approval of technologies (e.g., durability and other emissions testing) will affect the cost structure of the industry. However, since government primarily affects industry competition through the above-mentioned competitive forces, it was not considered a force in and of itself.

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2.4 Industry Structure

The conversion industry structure is closely related to the technological approaches that have been used in conversions. Historically, conversions have been done on a one-by-one basis, which left little scope for significant engineering. Conversion kits tended to be fairly generic (i.e., "one size fits all"). The resulting "loose" industry structure is depicted in Exhibit 2-2. OEMs have a small percentage of the AFV fleet market. Engineered converters work primarily in concert with OEMs, but are starting to work directly with fleet customers.

Kit makers generally sell their kits to distributors, which in turn, sell them to installers. The two primary kinds of installers are gas companies and small, "mom and pop" auto shops. However, some kit makers vertically integrate by owning installation facilities. One advantage of doing this is that the kit maker has more control over the quality of the conversions performed with its products.

The industry characteristics discussed in Section 2.2 and the competitive forces discussed in Section 2.3 are forcing the aftermarket conversion industry to change, thereby causing major shifts in commercial relationships. Importantly, there is a trend toward vertical integration (whereby one company makes and installs kits) and having authorized installers (much like current automakers have authorized dealers). For example, one currently may get a vehicle converted using Stewart & Stevenson or BKM technology only by going to authorized, trained installers. For the installer to purchase Stewart & Stevenson and ANGI equipment, s/he must attend multi-day training courses at company facilities. Stewart & Stevenson also requires installers to use a laptop computer to install its kit and adjust the vehicle's fuel system. Industry practices such as this will improve the quality of conversions and increase the credibility of a specific firm and the industry as a whole. Such trends will effectively realign the industry.

ICF's projection of the structure of the industry in five to ten years is shown in Exhibit 2-3. OEMs may supply 25 to 50 percent of fleet AFVs and are beginning to make AFVs available to the public in general. Engineered converters hold a larger share of the market than in 1992 and work with both fleets and OEMs. There will be a smaller set of technology-driven, vertically-integrated firms producing conversion kits. These firms typically will be either traditional kit makers or gas companies that have entered the kit business via acquisition or joint venture in order to stimulate vehicle demand for natural gas. Distributors will function much as they currently do; however, fewer kits may be sold through them as vertical integration increases and kit makers ship kits directly to authorized installers. As discussed above, the majority of installers will be authorized to convert vehicles using kits from one or more kit makers. Many of these authorized installers will be the same companies that currently perform conversions, namely gas companies and small auto shops. However, we expect there will be a trend toward larger installation centers to obtain economies of scale. In addition, some larger fleets may work out agreements with kit makers to allow fleets to convert their vehicles in-house.
EXHIBIT 2-2
CURRENT STRUCTURE OF THE AFTERMARKET CONVERSION INDUSTRY

INDUSTRY

OEMs

ENGINEERED CONVERTERS

DISTRIBUTORS

KIT MAKERS

VERTICALLY INTEGRATED INSTALLERS

GAS COMPANY INSTALLERS

"MOM & POP" INSTALLERS

CUSTOMERS
EXHIBIT 2-3
PROJECTED STRUCTURE OF THE AFTERMARKET CONVERSION INDUSTRY

OEMs → ENGINEERED CONVERTERS

VERTICALLY INTEGRATED KIT MAKERS OR FUEL SUPPLIERS

DISTRIBUTORS

AUTHORIZED INSTALLERS OR FLEET CUSTOMERS

INDUSTRY

CUSTOMERS
CHAPTER 3
INDUSTRY SEGMENTS AND MODEL COMPANIES

There are approximately 60 firms currently participating in the aftermarket conversion industry. As discussed previously, these firms can be categorized by their activities into three primary segments (kit makers, installers, and engineered converters). Exhibit 3-1 provides names of companies currently participating in the aftermarket conversion industry. This chapter discusses the characteristics of each segment and presents financial profiles of representative model companies for each segment.

3.1 Kit Makers

There are currently 15 US companies manufacturing or assembling conversion kits. The majority of these companies (10) are industrial equipment manufacturers or wholesalers. The others are fuel or engineering companies. While no exact information on market share is available, two companies, IMPCO Technologies (IMPCO) and Automotive Natural Gas Inc. (ANGI), account for an estimated 70 percent to 90 percent of kit sales. Both of these manufacturers produce both CNG and LPG kits for all EPA vehicle classes. Several of the kit makers (e.g., Stewart & Stevenson) only began selling conversion kits this year.

There is no readily available information on the annual number of kits sold by, nor the number of kit/engine family combinations provided by, each kit maker. Kits often vary with the model year of the vehicle as well as with the technological sophistication of the componentry. ANGI, for example, has 159 CNG kit types certified by the Colorado State Department of Health.\textsuperscript{10} Exhibit 3-2 lists kit makers and indicates whether they produce CNG and/or LPG kits and if they have received any type of certification for them.

As mentioned in Chapter 2, kit technology is changing rapidly. There is the potential for a shake-out as kit makers who do not have closed-loop air/fuel control technology (which is necessary to bring NO\textsubscript{x} emissions from converted cars to below CAA standards) are forced out of the industry. This would result in a smaller set of high-technology companies. In view of the offsetting effects of growth in demand, technology, and start-up firms on one hand, and the possibility of consolidation on the other, ICF expects that the total number of kit makers in 2000 will be similar to the current total of about 15.

\textsuperscript{10} Twenty-eight of these kits are certified for use in light-duty gasoline powered passenger cars, 73 for light-duty gasoline powered trucks, and 58 for heavy-duty gasoline powered trucks.
### EXHIBIT 3-1
### COMPANIES IN THE AFTERMARKET CONVERSION INDUSTRY

#### KIT MAKERS
- Algas Industries Inc.
- Automotive Natural Gas
- BKM, Inc.
- Bowgen Fuel Systems
- Carburetion Lab
- CleanFuels, Inc.
- Garretson Equipment
- IMPCO Technologies
- Metropane, Inc.
- Mogas Inc.
- National Energy Service Co.
- Natural Gas Resources
- OHG Inc.
- Propane Equipment Corp.
- Stewart & Stevenson Power, Inc.

#### ENGINEERED CONVERTERS
- BKM, Inc.
- Cars and Concepts
- Clean Air Partners
- IMPCO Technologies
- Intelligent Controls
- NGV Technology Center
- Stewart & Stevenson
- Tecogen, Inc.

#### INSTALLERS
- Amerigas
- Autocraft, Inc.
- Automotive Natural Gas
- BKM, Inc.
- Bus Manufacturing USA
- Carburetion Lab
- Carburetion & Turbo Systems
- City Spring
- CleanFuels, Inc.
- CNG Fuel Converters
- CNG Technologies Corp.
- CNG Corp.
- Crane Carrier Co.
- Dallas Fleet Maintenance
- Detsco, Inc.
- Ecogas
- Ferrellgas, Inc.
- IMPCO Technologies
- Mesa Operating Ltd Partnership
- Motorfuelers
- National Energy Service Co.
- Natural Fuels Corp.
- Natural Gas Resources
- Northern Indiana Public Service Co.
- Pacific Gas & Electric
- Petrolane, Inc.
- Southern Cal Gas Co.
- Stewart & Stevenson Power, Inc.
- Tom Gorman Company
- Tren Fuels
- Tri-Fuels, Inc.
- Washington Gas & Light Co.
**EXHIBIT 3-2**

**List of Kit Makers by Kit Type and Certification**

<table>
<thead>
<tr>
<th>Company</th>
<th>CNG Kit</th>
<th>LPG Kit</th>
<th>Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algas Industries Inc.</td>
<td></td>
<td>x</td>
<td>CARB</td>
</tr>
<tr>
<td>Automotive Natural Gas</td>
<td>x</td>
<td>x</td>
<td>AGA, CARB, CO Dept. of Health</td>
</tr>
<tr>
<td>BKM, Inc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowgen Fuel Systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carburetion Lab</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>CleanFuels, Inc.</td>
<td></td>
<td>x</td>
<td>AGA</td>
</tr>
<tr>
<td>Garretson Equipment</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>IMPCO Technologies</td>
<td>x</td>
<td>x</td>
<td>CARB, CO Dept. of Health</td>
</tr>
<tr>
<td>Metropane, Inc.</td>
<td></td>
<td></td>
<td>AGA</td>
</tr>
<tr>
<td>Megas Inc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Energy Service Co.</td>
<td>x</td>
<td></td>
<td>AGA</td>
</tr>
<tr>
<td>Natural Gas Resources</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>OHG Inc.</td>
<td></td>
<td>x</td>
<td>CARB</td>
</tr>
<tr>
<td>Propane Equipment Corp.</td>
<td>x</td>
<td>x</td>
<td>AGA</td>
</tr>
<tr>
<td>Stewart &amp; Stevenson Power, Inc.</td>
<td>x</td>
<td></td>
<td>CARB (pending)</td>
</tr>
</tbody>
</table>
There is no comprehensive information available on the split among the kit makers between heavy- and light-duty vehicle conversion kits. Available information suggests that all kit makers will sell light-duty vehicle kits while only about two-thirds of kit makers (about 10) will sell kits for heavy-duty vehicles.

Exhibit 3-3 provides financial profiles for three different sizes of kit makers. There is a substantial difference between the resources of the median large and the median small company profiles. The median large company has over 20 times the sales, and almost 10 times the assets, of the median small company. However, the median large company sells only two and one half times as many kits as the median small company. This reflects the fact that the larger kit makers tend to be diversified and obtain most of their income from other industries. The smaller companies tend to be more focused on the conversion industry and are benefiting from rapid industry growth (as evidenced by a return on assets of 9.5 percent). However, is there no clear indication whether size is correlated with the technological sophistication of a company’s kits. Technology will be one of the key determinants of a company’s success in this industry.

**EXHIBIT 3-3**  
**1992 FINANCIAL PROFILES OF KIT MAKERS**

<table>
<thead>
<tr>
<th></th>
<th>Lower Quartile Small Company</th>
<th>Median Small Company</th>
<th>Median Large Company</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Employees</strong></td>
<td>10</td>
<td>16</td>
<td>185</td>
</tr>
<tr>
<td><strong>Sales</strong></td>
<td>$1,777,300</td>
<td>$2,540,700</td>
<td>$30,530,400</td>
</tr>
<tr>
<td><strong>Profits</strong></td>
<td>$134,100</td>
<td>$207,100</td>
<td>$953,200</td>
</tr>
<tr>
<td><strong>Assets</strong></td>
<td>$1,411,500</td>
<td>$2,180,300</td>
<td>$19,249,600</td>
</tr>
<tr>
<td><strong>Return on Assets</strong></td>
<td>9.5%</td>
<td>9.5%</td>
<td>4.9%</td>
</tr>
<tr>
<td><strong>Working Capital</strong></td>
<td>$222,200</td>
<td>$317,600</td>
<td>$3,816,300</td>
</tr>
<tr>
<td><strong>Net Worth</strong></td>
<td>$470,000</td>
<td>$726,000</td>
<td>$6,410,100</td>
</tr>
<tr>
<td><strong>Projected Number of Kits Sold in the Year 2000</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CFF Regulations</strong></td>
<td>1,000</td>
<td>2,000</td>
<td>5,000</td>
</tr>
<tr>
<td><strong>Gaseous Fuels Regulations</strong></td>
<td>3,000</td>
<td>6,000</td>
<td>15,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4,000</td>
<td>8,000</td>
<td>20,000</td>
</tr>
</tbody>
</table>
3.2 Installers

There are more than 40 companies performing CNG and LPG conversions in the US today. While these companies are located across the US, many new companies are entering the industry in states with strong alternative fuel legislation (e.g., Texas and Oklahoma). The number of conversion companies is expected to increase rapidly, especially in states that pass new legislation and in non-attainment areas. By 2000, ICF expects that the total will rise to as many as 120 installers, with a substantial majority (about 100 of the 120) located in the high-demand non-attainment areas. A large fraction of these installers will be performing conversions capable of meeting federal CFF standards, with the rest serving economic demands and state-driven demands. In addition, only a fraction of these (perhaps a third) are likely to offer heavy-duty conversions, due to the substantially lower total demand for heavy- as opposed to light-duty CFF vehicles.

Currently, there are four types of conversion companies: vertically-integrated kit makers; suppliers/distributors of fuels, or providers of fuel services (i.e., utilities); auto repair shops; and small, start-up companies that are dedicated to conversions. Each type of company is notably different in terms of size and competitive position.

Vertically-integrated kit makers such as IMPCO have always performed some conversions; however, they are expected to do more as demand for AFVs grows. They have several potential advantages over other installers including lower price (since they obtain the kits at cost) and in-depth knowledge of the technology in their kit. Companies authorized to use specific kits may also benefit from these advantages.

Fuel companies and gas utilities have historically dominated the conversion segment. They are also the largest consumers of conversion kits and other conversion equipment. Although some companies supported gaseous fuels initiatives earlier, most gas utility companies began their involvement in the aftermarket vehicle conversion industry in the early seventies (1972-74) when gasoline prices (world market) were high. To avoid paying the high prices of gasoline and to take advantage of the cost advantages of CNG and LPG, utility companies began converting their fleet vehicles to use gas. These conversions tended to be relatively low-tech and were not carefully checked for emissions. Today, many gas utility companies own conversion facilities and are beginning to offer conversion services to outside fleet operations (such as city police departments and school districts). Locally, utility companies provide the majority of installation services. Even though utility companies may have a significant role in the local market, the utility conversion businesses are a small percentage of the companies' revenues (less than one percent) and sometimes represent a loss of net revenue.

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11 This estimate does not include distributors nor the thousands of gas and utility companies who perform occasional conversions on their own vehicles.

12 School districts and other municipal operations with fleets are the other large consumers of these products.

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In general, the number of conversions performed by individual utility and gas companies per year is fairly small (fewer than 100); some, however, such as Southern Union Gas and Enfuel13 (both in Houston, Texas), have conversion centers capable of converting on the order of 1,000 conversions per year. It is estimated that three large LPG conversion companies (Petroleum, Ferrellgas, and Amerigas) account for about half of LPG conversions. These large conversion centers experience significant economies of scale. They are able to buy supplies and equipment in bulk, and purchase only the components they need rather than complete kits. In addition, these companies perform conversions at or near cost to promote the use of natural or propane gas as a fuel (they will earn profits from the future sale of fuel to the converted vehicles). Their ability to provide these services at or near cost enables them to submit low bids for contracts to perform fleet conversions. Smaller companies, whose primary business may be conversions, often cannot afford to compete with utility companies' low bids for these contracts.

The third type of conversion company, auto-repair shops, offers conversion services as a side-line business. They tend to be small (fewer than 15 employees) and have performed a minimal number of conversions (perhaps one to twenty). In general, these companies probably will not invest large amounts of money in conversion equipment or become major players in the industry. However, there may be profitable niches for some companies who provide fleet maintenance services, for example.

The fourth type of conversion company, dedicated conversion companies, currently is similar in size to auto-repair shops. However, they are committed to capitalizing on conversion opportunities brought about by the CAA. They tend to be start-up companies and are fairly vulnerable - they have not yet converted a significant number of cars and are in debt. These companies may have a difficult time obtaining loans to purchase the necessary conversion equipment and obtain the proper insurance. They are at a cost disadvantage relative to the larger conversion companies as they cannot purchase supplies in bulk nor offer conversions at cost.

As with auto-repair shops, these small conversion companies may be able to find niche or regional markets.14 They may also be able to become affiliated with one or more kit makers, thus gaining the resources and repute necessary to enable them to grow and compete with larger installers.

As in many industries, though relatively small installers are likely to predominate in terms of numbers, a substantial majority of all conversions will be performed by outlets performing more than 300 conversions per year. ICF expects that in the year 2000, about 100,000 vehicle conversions will be performed, though only about 37,000 of these will be attributable to the federal CFF requirements.15 Most of the conversions related to the

13 Enfuel's conversion center is expected to open in mid-1992.

14 Competition in the conversion segment is generally on a regional basis; fleets probably will not travel large distances to have their vehicles converted.

15 The basis for these estimates is presented in Chapter 4.
federal requirements can be expected to be performed within the 22 non-attainment areas. Some (roughly 10 percent) will be performed outside of the non-attainment areas but close enough to serve the demand originating within them.

Exhibit 3-4 presents financial profiles for three different sizes of conversion companies.

**EXHIBIT 3-4**

**1992 FINANCIAL PROFILES OF INSTALLERS**

<table>
<thead>
<tr>
<th>Employees</th>
<th>Lower Quartile Small Company</th>
<th>Median Small Company</th>
<th>Median Large Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees</td>
<td>3</td>
<td>15</td>
<td>2,800</td>
</tr>
<tr>
<td>Sales</td>
<td>$480,000</td>
<td>$1,200,000</td>
<td>$262,000,000</td>
</tr>
<tr>
<td>Profits</td>
<td>$1,100</td>
<td>$6,100</td>
<td>$42,584,700</td>
</tr>
<tr>
<td>Assets</td>
<td>$184,900</td>
<td>$1,016,500</td>
<td>$1,013,921,000</td>
</tr>
<tr>
<td>Return on Assets</td>
<td>0.6%</td>
<td>0.6%</td>
<td>4.2%</td>
</tr>
<tr>
<td>Working Capital</td>
<td>$80,200</td>
<td>$200,400</td>
<td>$21,746,000</td>
</tr>
<tr>
<td>Net Worth</td>
<td>$110,900</td>
<td>$609,900</td>
<td>$253,480,300</td>
</tr>
<tr>
<td>Projected Number of Installations in the Year 2000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFF Regulations</td>
<td>100</td>
<td>400</td>
<td>1,000</td>
</tr>
<tr>
<td>Gaseous Fuels</td>
<td>300</td>
<td>1,200</td>
<td>3,000</td>
</tr>
<tr>
<td>Regulations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>400</td>
<td>1,600</td>
<td>4,000</td>
</tr>
</tbody>
</table>

3.3 Engineered Converters

Engineered converters are firms investing substantial engineering resources in developing and optimizing a conversion system for a specific vehicle model. Since the cost of this optimization, emissions certification, etc., can easily run as high as $100,000 to $500,000, costs must be recovered through significant sales volumes (typically over 500 vehicles per year). Engineered converters frequently work in concert with an OEM, and are increasingly working with large fleets. The GM pickup trucks and Ford Crown Victoria NGVs are being produced in this way. In the future, these types of firms are expected to dominate the conversion industry.

ICF has identified eight firms that perform engineered conversions. Three of these firms are also kit makers (BKM, Impco, and Stewart & Stevenson), four are specialty engineering firms (Cars and Concepts, Clean Air Partners, Intelligent Controls, and Tecogen Inc.), and one
(NGV Technology Center) is a joint venture between Southern Union Gas Company and NGV Development Corporation. As with the kit makers, ICF expects that the total number of engineered converters will be approximately the same in 2000 as at present; thus, the total number of firms certifying kits will be between 20 and 25. All or virtually all are expected to be involved in light-duty conversions; many (roughly ten) will offer a kit or conversion for at least one heavy-duty engine.

Five of the engineered converters are located in non-attainment areas; a sixth is located in Texas, which has recently passed alternative fuels legislation. In five years, ICF expects that most engineered converters will be found within non-attainment areas, as a result of the growing demand for emissions-related conversions there.

While engineered conversion companies are generally small, both in terms of sales and employees, they are expected to grow significantly in the next ten years. Exhibit 3-5 provides financial profiles of three different sizes of engineered converters.

<table>
<thead>
<tr>
<th></th>
<th>Lower Quartile Small Company</th>
<th>Median Small Company</th>
<th>Median Large Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees</td>
<td>9</td>
<td>25</td>
<td>188</td>
</tr>
<tr>
<td>Sales</td>
<td>$759,700</td>
<td>$2,523,300</td>
<td>$23,815,200</td>
</tr>
<tr>
<td>Profits</td>
<td>$0</td>
<td>$290,600</td>
<td>$658,700</td>
</tr>
<tr>
<td>Assets</td>
<td>$1,230,800</td>
<td>$3,264,700</td>
<td>$21,957,800</td>
</tr>
<tr>
<td>Return on Assets</td>
<td>0.0%</td>
<td>8.9%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Working Capital</td>
<td>$95,000</td>
<td>$315,400</td>
<td>$2,976,900</td>
</tr>
<tr>
<td>Net Worth</td>
<td>$409,900</td>
<td>$1,087,100</td>
<td>$7,311,900</td>
</tr>
<tr>
<td>Projected Number of Conversions in the Year 2000*</td>
<td>450</td>
<td>900</td>
<td>6,000</td>
</tr>
</tbody>
</table>

* These projections do not include vehicles that engineered converters produce with OEMs.

Sales of the median large company are approximately nine times the sales of the median small company, which are, in turn, approximately three times the sales of the lower quartile small company. There does not appear to be a strong correlation between company
size and return on assets (ROA): the median small company has the highest ROA at 8.9%. This could reflect the fact that the larger engineered converters tend to be diversified (and, therefore, may gain the majority of their revenues from other, slower growing, businesses) and the smallest engineered converters are essentially start-ups (which have performed few conversions at this time).
CHAPTER 4
DEMAND FOR INDUSTRY PRODUCTS AND SERVICES

Demand for the products and services of the various segments of the industry--conversion parts, kits, and installations--are ultimately derived from the demand for converted vehicles. For this reason, a brief examination of the reasons for owning gaseous fueled vehicles is worthwhile.

As mentioned in the introduction to this report, AFVs have many potential benefits including cleaner emissions and low fuel costs and vehicle maintenance. However, the choice of a converting a vehicle to use gaseous fuel also has several negatives sides: the expense of the initial conversion; greater weight and reduced carrying capacity; generally shorter range on the gaseous fuel; uncertain gaseous refueling at locations other than the vehicles' home bases; and costs for fueling centers. The problems related to range and fueling uncertainty are particularly important for dedicated gaseous fuel vehicles. For a vehicle owner to choose to convert to gaseous fuel (especially if the conversion is to a dedicated gaseous fuel vehicle), he or she must see advantages that outweigh these drawbacks.

4.1 Demand Based on Economic Factors

Up to the present, the main advantages of gaseous fuel conversions were economic. Depending on relative costs and availability of different fuels, natural gas and LPG vehicles can have significantly lower operating costs and greater actual or perceived security of supply. If an alternative fuel costs on the order of half as much as gasoline on an energy-equivalent basis vehicle owners can save hundreds of dollars per vehicle on fuel every year by converting. The fuel cost per mile for a natural gas-fueled car, for example, has been estimated by the American Gas Association at 1.6 cents per mile in comparison with a cost of 3.6 cents per mile for a comparable gasoline-powered car. (It was assumed that the car travelled 25 miles per gallon of gasoline, that the cost of gasoline was $1.21 per gallon, that uncompressed natural gas cost $3.15 per million Btu, and that the energy efficiency of the car was the same for both fuels.) Savings of two cents per mile amount to $300 per year for a vehicle traveling 15,000 miles per year. Vehicles that are used more intensively, and vehicles that use more fuel per mile, will show greater savings. Potentially lower maintenance costs and greater certainty of supply (in the face of gasoline rationing, for example) can contribute even more to the advantages of gaseous fueled vehicles. Whether savings of this

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magnitude can be achieved depends a great deal on matters such as whether the vehicle is optimized for gaseous fuels, and on tax requirements for CNG/LPG relative to gasoline.\(^7\)

Whether these advantages outweigh the costs of the initial outlay on conversions and refueling facilities (in addition to the range, weight, and capacity tradeoffs) depend in part on

- The cost of the alternative fuel,
- The certainty of the supply of the alternative fuel,
- The number of vehicles using each refueling center, and
- The availability and cost of capital for up-front expenses.

Fleets will be the most likely candidates for conversion in part because they have relatively high annual mileage per vehicle and many vehicles over which to spread the costs of the refueling system. Fuel suppliers (natural gas and propane distributors) will also be good prospects because they will face particularly low fuel costs (wholesale rather than retail) and will have a relatively certain supply. Finally, regulated utilities that are able to raise capital at low effective cost will have an additional reason to convert.\(^8\) Given these factors, it is understandable that the fleets of fuel suppliers (including natural gas utilities) are prominent among existing conversions. Other types of fleets include package delivery services such as Federal Express and UPS; repair vehicles such as telephone and electric companies; beverage distributors; and local governments and school districts in many states.

It has been estimated that there are almost half a million gaseous-fueled vehicles in the United States—30,000 using CNG and 425,000 using LPG.\(^9\) No firm estimates of the current rate of gaseous fuels conversions are available. It is reasonable to estimate, however, that between 5,000 to 8,000 CNG conversions and 70,000 to 100,000 LPG conversions are being performed annually, for a total in the range of 90,000 per year.\(^10\)

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\(^7\) See Environmental Protection Agency, Office of Mobile Sources, Special Report, Analysis of the Economic and Environmental Impacts of Compressed Natural Gas as a Vehicle Fuel, Volumes 1 and 2, April 1990.

\(^8\) Most rate-regulated utilities are able to cover the costs of approved capital investments through rate increases. Thus, they can be more favorably disposed toward making capital investments than are businesses for whom an investment poses risks.


\(^10\) If the total stock of converted vehicles is growing by ten percent per year (a moderate growth rate for a relative new market segment) 3,000 CNG conversions and 42,500 LPG conversions would be required even if no existing vehicles had to be replaced. An additional 3,000 CNG and 42,500 LPG conversions would be needed to replace existing vehicles even if only 10 percent of the stock were scrapped each year. The ranges presented in the text allow for the considerable uncertainty in the estimates of growth and scrappage rates.
Numerous factors will influence the future demand for gaseous-fueled conversions. By the year 2000, total demand for gaseous-fueled vehicles for economic reasons will have grown from the range of 90,000 per year to almost 200,000 per year if demand grows at ten percent per year from 1992 to 2000; this growth rate would not be out of line for relatively new industry with a favorable economic basis and a growing availability of products and infrastructure. ICF expects the growth rate to be even higher than ten percent, for three reasons. First, OEMs are expected to enter the market with lower-cost gaseous fueled vehicles. The OEM vehicles should achieve significant market penetration because of the lower costs of their offerings (due to economies of scale) and because purchasing from a major carmaker is a more familiar action than engaging an aftermarket converter. Second, tax credits are likely to become available for gaseous-fueled vehicles. Finally, as the refueling infrastructure expands, the convenience of using a gaseous-fueled vehicle will increase. ICF estimates that these three factors could push economically driven demand for gaseous-fueled vehicles above 300,000 per year by 2000.21

Some of the economically-driven demand for gaseous-fueled vehicles is likely to overlap with the demand driven by air quality concerns (covered in Section 4.2). We have assumed that half of the economically driven demand in the non-attainment areas is preempted by the Federal CFF regulations and similar regulatory initiatives, which apply in areas with almost thirty percent of vehicle sales. We have therefore reduced our estimate of the sales of gaseous-fueled vehicles for strictly economic motives is reduced by 15 percent to about 250,000 per year by 2000.

Not all of these economically driven sales will be conversions of gasoline fueled vehicles: because a total market of 250,000 vehicles is large enough for mass production of a variety of models, OEMs are likely to be the most important factor in the market for economically driven gaseous-fueled vehicles. However, it is difficult to estimate the percentage of these gaseous-fueled vehicles which will come from conversions, and no estimate is made here.

Of these sales, ICF assumes that almost all will be light-duty vehicles, with about four percent (or 3,000 vehicles) in the heavy-duty category. This division between light and heavy-duty vehicles is a rough estimate, based on EPA’s estimates for the Federal CFF program (see Section 4.2.2 below).

4.2 Demand Related to Air Quality and Regulation

The potential emission control advantages of gaseous fuels have, until now, been a secondary consideration in the decision to convert. Clean fuel fleet regulations resulting from the 1990 amendments to the Clean Air Act, in addition to related state initiatives, have

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21 This increase of 50 percent in demand, from 200,000 to 300,000, is based on rough assumptions that favorable tax treatment and cost reductions could bring the net cost of a conversion down by $1,000, and ICF’s estimate (presented below in this chapter and in Appendix B) that each $100 drop in price could lead to between a four and eight percent increase in the quantity demanded.
introduced a major new component to gaseous fuel vehicle demand. Requirements to convert larger fractions of fleets to alternative or clean fuels place gaseous fuels in a separate competition with electric, methanol, ethanol, and (to some extent) reformulated gasoline-powered vehicles.

Where the definition of clean-fuel vehicle excludes reformulated gasoline (as in Texas), gaseous-fueled vehicles have a clear chance to capture a large share of the clean-fuel segment of the market due in part to the limited availability and high costs of electric vehicles and alcohol fuels. Even where gaseous-fueled vehicles are in competition with reformulated gasoline for the clean-fuel market, the higher costs of reformulated gasoline, active participation by the gas companies, and the potentially lower emissions from gaseous fuels could lead to significant demand for gaseous fuel conversions. This demand is likely to be pushed further by EPA’s Inherently Low Emission Vehicle (ILEV) incentive program.

4.2.1 Light-duty Demand Related to Air Quality and Regulation

The majority of the vehicles affected by air quality regulations will be light-duty vehicles (passenger cars and light trucks). Estimated sales of emissions-driven gaseous fueled light-duty vehicles can be divided into three groups: sales driven directly by California’s regulations; sales driven by the Federal CFF regulations for non-attainment areas outside of California; and sales driven by state clean air initiatives outside of California that go beyond the federal program in geographic coverage or in scope. However, this analysis focuses only on clean fuel fleet vehicles.

Sales of light-duty clean-fuel fleet vehicles that are driven directly by the Federal CFF rules have been estimated by EPA at 209,000 in the year 2000. Of these, EPA expects no more than 25 percent (52,300 per year) to be gaseous fueled, and estimates that OEM penetration will be about 30 percent. Thus, the Federal CFF standards will result in almost light-duty 37,000 conversions per year by the year 2000. This estimate of the percentage of these vehicles that will be supplied by the OEMs is based on an examination of potential economies of scale in supplying vehicles in response to the Federal CFF standards in isolation. Considering the broader market for gaseous-fueled vehicles driven by the California program, other state programs, and economically driven demand, ultimately a larger fraction of Federal CFF demand may be met by OEMs, and a smaller fraction by conversions.

The split between CNG and LPG is currently uncertain. Industry groups have confidence in their own products, as one would expect: the American Gas Association projects that between 40 and 60 percent of clean fuel vehicles will run on natural gas, while an LPG group reports a survey showing that LPG’s share will be two to three times that of electric or CNG vehicles.

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22 Office of Mobile Sources memorandum to ICF Inc., Estimates of Gaseous Fuels OEMs and Conversions, July 9, 1992.

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4.2.2 Heavy-duty Demand Related to Air Quality and Regulation

A small number of gaseous fuel conversions will be of heavy-duty vehicles. EPA estimates that by the year 2000, the Federal CFF program will result in an annual demand for no more than 2,500 gaseous fueled heavy-duty vehicles, of which about 1,500 will be conversions and 1,000 will be supplied by OEMs. Sales of 1,500 amount to only about four percent of the 37,000 light-duty conversions driven by the Federal CFF program.

4.3 Interaction of Market Segments

In light of the preceding sections, it is apparent that there are two relatively distinct segments to the demand for gaseous fueled vehicles: the existing segment, driven by economic considerations; and a new segment, driven largely by clean fuel fleet requirements. The distinction between these demand segments is not absolute. First, economic considerations will affect the demand for clean fuel vehicles of different types relative to one another. In addition, the emission reduction benefits of gaseous fueled vehicles may in some cases add to their economic attractiveness in the eyes of vehicle owners not covered by clean fuel fleet requirements (e.g., if clean fuel vehicles earn Transportation Control Measure (TCM) exemptions, such as exemptions from high-occupancy vehicle (HOV) lane restrictions, or where clean fuel vehicles earn marketable credits), and the cost advantages of gaseous fuels will be enhanced in areas in which reformulated gasoline is required for all gasoline-fueled vehicles.

An additional connection between the clean fuel based demand segment and the economic-based demand may arise as a result of the spread of refueling outlets. Increases in the stock of gaseous fueled vehicles resulting from the clean fuel fleet program may create a demand for public refueling stations. By increasing the availability of fuel, an expanded refueling network will reinforce the economic-based demand for gaseous fueled vehicles. This effect is not likely to develop until there are substantial numbers of clean fuel vehicles on the road.

4.4 Elasticity of Demand

Whether or not there are regulations mandating the use of clean fuels, there will be no guaranteed market for any particular provider of gaseous fuel conversion products or services. Instead, market penetration will be a function of all costs and benefits to the potential purchasers. If the costs of conversions rise for an individual business or for an entire industry segment (all other things equal), the number of conversions demanded will be reduced.
The extent to which demand will fall off in response to a given increase in price cannot be predicted with any degree of certainty. Order-of-magnitude estimates can be made fairly easily, however, for two of the most important classes of situations:

(1) Where prices are increased by a single supplier of a relatively standard conversion part or installation service; and

(2) Where prices are increased by all suppliers of conversion parts or services.

In the first class of situations, demand can be expected to be quite sensitive to small price changes, for the same reason that prices of comparable grades of gasoline in the same area match closely: if an individual station raises its price by more than a few cents, it loses its customers to its competitors. Only those individual suppliers offering special products or services, or serving a particular market niche, will be able to increase prices without seeing substantial reductions in sales.

In the second class of situations, in which prices are increased across an entire industry segment, the sensitivity of sales to price changes can be expected to be moderately low. In the demand segment in which gaseous fueled vehicles are in competition with gasoline powered vehicles, a conversion price increase of $100 might reduce the quantity demanded by between four and eight percent; similarly, a $100 price decrease might increase sales by four to eight percent. In the demand segment in which gaseous fuels are in competition with electric vehicles only, the sensitivity to price changes is likely to be considerably smaller. In a situation in which one type of gaseous fueled vehicle increased in price compared to another (e.g., if CNG rose in price compared to LPG), the price sensitivity might be relative higher (than if prices of all gaseous fueled vehicles rose), since these two segments of the industry are relatively close substitutes for one another.

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23 This rough estimate was made on the basis of estimating the change in the fraction of fleet vehicles for which a conversion to natural gas would no longer be cost effective after a first-cost increase of $100, using an estimate of the distribution of miles travelled per year for different fleet vehicles. See Appendix B.

24 This estimate is based on estimates of the demand for electric vehicles as a function of the ratio between their lifecycle costs and the lifecycle costs of internal combustion vehicles. This analysis is presented in Appendix B.
CHAPTER 5
COST STRUCTURE OF THE AFTERMARKET CONVERSION INDUSTRY

An analysis of potential impacts of regulations that impose costs on the aftermarket conversion industry requires an assessment of the costs of providing conversion products and services, including an assessment of the relationship of costs to the size of the business. This chapter provides an overview of the price of conversions (which reflects in large part the full acquisition costs of conversions); the components that influence conversion costs; the relationship between costs and the scale of the conversion operation; and the potential costs of gaseous fueled vehicles from OEMs.

5.1 Conversion Prices

The price for converting a vehicle to use gaseous fuels at the present time depends both on the type of fuel to be used (CNG or LPG) and the size of the vehicle (light-duty or heavy-duty). Estimates of the price of a CNG conversion for a light-duty vehicle vary from $2,000 to $3,500; the low end of this range may reflect lower-pressure fuel storage cylinders and simpler open-loop technologies that are not likely to meet strict emission standards. Converting to LPG is less expensive, ranging from $1,000 to $2,000 for a light-duty vehicle. These estimates of the costs for light-duty CNG conversions are consistent with EPA's recent estimates of $2,550 to $3250. Conversions for heavy-duty vehicles are more expensive: a minimum of $3,500 for converting a gasoline engine to CNG, and $7,000 to $10,000 for LPG. Gaseous fuels conversions for heavy-duty diesel engines are even more expensive, with costs for converting to CNG estimated at between $12,000 and $30,000.

Gaseous fuel vehicle prices are expected to drop in the future through mass production and the participation of original equipment manufacturers (OEMs). The added cost of a light-duty CNG vehicle from an OEM is projected to be between $800 and $1,600 for CNG at large production levels; a similar range is projected for propane vehicles.


28 Final Report of Governor's Task Force, Tables 5.5 and 5.6, and p. 63.

29 Idem.

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5.2 Components of Conversion Costs

Conversion costs can be divided into the costs for the kits; the fuel storage cylinders; and installation. Among the more technologically advanced kits, projected prices range from $1,100 to $4,000 at high production volumes. Fuel cylinder costs will depend on the required fuel capacity and on the type of fuel. A typical value for CNG is $1,000 per vehicle; fuel storage costs for LPG are lower due to the smaller volumes and lower pressures required.

Costs for installations depend on the costs of labor, facilities, and equipment. Currently, a gaseous fuel conversion takes about 20 labor hours. At a typical rate for auto repair facilities of $40 per hour for trained labor, including a markup to cover benefits, overhead, and profit, labor would be billed at $800 per conversion. Adding this cost to the costs for fuel storage and a conversion kit produces a cost of $2,900 for a CNG conversion for a light-duty vehicle.

A straight labor-hour calculation oversimplifies the full costs of installation, however, especially for a small facility. Workers must complete training courses before being certified to perform conversions; one kit supplier requires a multi-day training course at its own facility. Beyond this formal training, installers need extensive experience to perform efficiently. Thus, an installation business needs to make significant investments in labor before it can compete effectively, and this investment must be amortized over the conversions performed. In addition to its investments in labor, installers of sophisticated conversion kits need equipment, including a dynamometer and electronic testing equipment to ensure that the conversions are performed correctly. Dynamometers cost $35,000, and the rest of the specialized equipment brings the investment in test equipment to about $50,000. Installers also require liability insurance, which may be difficult to obtain for small operations. The total investment required for a new conversion operation may be $250,000, including training, equipment, and initial inventory. As this investment must be spread over the income earned from conversions, low-volume operations will have higher unit costs.

Amortization of equipment will depend on the discount rate, the number of years that the equipment can be used, and the number of conversions per year. To amortize $50,000 in equipment over 5 years, with a 10 percent discount rate, is about $13,000 per year. To spread this investment over 250 conversions per year (or one per day) would mean a per-unit cost of about $50, which is a relatively small fraction of the total cost of a conversion.

5.3 Economies of scale

One LPG group has asserted that economies of scale in installations are small due to extensive labor on individual vehicles, rather than on assembly lines. However, there are likely to be substantial economies in larger volume part or kit orders; in fully utilizing equipment, and in developing labor skills. As in the example presented above, spreading $50,000 worth of specialized testing equipment over 250 conversions per year for five years

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30 Conversations with Stewart and Stevenson and Christopher Weaver of EF&EE.
amounts to only about $50 per conversion. Spreading the costs over only 50 conversions a year, or one per week, raises the unit cost by a factor of five to about $250. Similarly, at 1,000 conversions per year the unit cost falls to less than half of one percent of the total cost of the conversion. In the carefully studied "learning curve" phenomenon, it has been found that each doubling of cumulative output can cut labor inputs by 20 percent. Thus, a facility where cumulative volumes are eight times greater (as in dedicated facilities where workers install conversion kits full time), labor costs are expected to be only half as great. Thus, costs would be in the neighborhood of $2,500, or perhaps less, depending on the economies of scale in larger volume kit orders.

5.4 OEM Competition

Eventually, OEMs will compete strongly in the market for gaseous fueled vehicles. Their advantages include greater buying power; the efficiencies of the assembly line; and savings on parts that do not have to be added only to be removed at the time of conversion. One estimate is that OEM gaseous fueled vehicles will cost only $800 more as opposed to $2,500 more for retrofit gaseous fueled vehicles. Still, models on which OEM will offer gaseous fuel option is likely to be limited to those for which substantial sales are possible (for example, 10,000 units per year). Limited offerings by OEMs will leave substantial sales opportunities for aftermarket conversions both for economic and clean fuel uses.

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31 Assumes that $50,000 is amortized over five years at a real discount rate of 10 percent, and that a conversion costs roughly $3,000 in all.


CHAPTER 6
PRELIMINARY ANALYSIS OF IMPACTS

Both the Gaseous Fuels and the Clean Fuel Fleet regulations will require that aftermarket conversions be performed with kits that have been certified by EPA to meet the applicable emissions standards. In addition, each converted clean fuel fleet vehicle may be required to pass a tailpipe test to ensure that the certified kit used for the conversion has been installed correctly.

These requirements will impose costs at three levels:

♦ An $80,000 durability test to “prove” a basic technology;
♦ A $10,000 low-mile emission test for each kit/engine family combination; and
♦ A $5 - $25 tailpipe test on each converted vehicle to verify the kit was properly installed.

For each of these levels, the following sections describe the requirements, assumptions regarding unit testing costs, projected number of tests, and impacts of the costs on the model firms.

6.1 Emission Tests

Given the relatively low annual sales expected for each kit/vehicle engine family combination, gaseous conversion kit makers will be considered small volume manufacturers for certification purposes. They will therefore be required to conduct low-mileage tests only for any kit using “proven technology.” Kits using “unproven technology,” on the other hand, will require a durability test to determine deterioration factors, in addition to meeting the standards at low mileage.

6.1.1 Unit Cost

Once a particular technology has undergone a durability test, the technology it uses will be considered “proven.” Subsequent kits certified using the same technology will therefore be required to pass a low-mile emission test only. EPA has estimated that each durability test will cost approximately $80,000, and that low mile emission tests for conversions will cost about $10,000.

6.1.2 Total Costs

EPA anticipates defining individual technologies broadly, meaning that a relatively small number of basic technologies will suffice to cover all conversion kits. While the exact number of technologies that will be used is necessarily uncertain given ongoing progress in the
industry, ICF expects the total number of basic technologies to range between 3 and 10. Thus, given per-test costs of $80,000, the total cost of the durability tests will range from $240,000 to $800,000 for the industry.

6.1.3 Incidence and Impact of Costs

Given that the technologies used for kits aimed at the Federal CFF standards are likely to overlap substantially with the technologies used for kits affected by the Gaseous Fuels standards, there is no meaningful way to attribute the costs of the durability tests to one set of rules or the other.

The total costs of the durability tests are minor when compared to the total number of conversions expected, or to the total revenues of the conversions industry. Assume the testing costs can be amortized over a five year period, they will amount to between $63,000 and $210,000 per year.\(^{34}\) Given that the volume of gaseous fuel conversions is expected to be in the range of 150,000 units per year, the durability testing costs will add less that two dollars per unit. This cost increase is an insignificant fraction of the $3,000 or greater cost of a typical conversion.

Because there are no statutory mechanisms to require sharing of the costs of durability tests, all of the costs will be born by the first firms to certify a kit using each basic technology. Other kit makers certifying kits that use the same technology as one of the "pioneering" firms will have the advantages of durability tests while incurring none of the costs. On the other hand, the pioneering firms will have the advantage of introducing a new technology somewhat earlier that the firms that follow.

Because durability testing costs are imposed only on the first firm to employ each technology, they take on the characteristics of sunk costs. A firm that has incurred a sunk cost (that is, a cost that is unrelated to its production volume) will not have an increased incentive to raise prices to recover them. Rather, the firm will want to keep its prices low, in order to generate enough sales volume to spread the up-front costs over more units. Thus, it is more appropriate to compare the testing costs to the assets and anticipated profits of the firms most likely to incur them than to compare these costs to revenues, or to estimate the increase in revenues needed to cover the costs.

Large kit makers and engineered converters are the most likely candidates for leadership in certifying unproven technologies. Estimates of the assets and profits of kit makers and engineered converters are presented in Exhibits 3.1.2 and 3.2.1. The large model firms in each of these industry segments are relatively similar in scale, with assets close to $20,000,000 and profits on the order of $800,000. For these firms, the costs of performing a durability test would clearly be manageable. A cost of $80,000 would be less than half of one percent of assets, indicating that financing the test would not be a problem, and the annualized cost of a test (of about $22,000) would have a minimal impact on profits of less than three percent. Even if a median small company found it necessary to perform a

\(^{34}\) Assumes that costs $240,000 to $800,000 are amortized over five years at a 10 percent discount rate.
durability test, the impacts on assets and profits would be relatively low: $80,000 is on the order of a few percent of the assets of median small kit makers and engineered converters, and the annualized testing cost of $22,000 is no more than a tenth of profits, which are currently strong for firms of this size.

6.2 Low-mile Certification Tests

Low-mileage certification tests will be required both for gaseous fuel and clean fuel fleet conversions kits. An attempt is made to separate the costs attributable to these two programs individually, though there is likely to be considerable overlap in the demand for vehicles certified under the two programs. The cost of each test is expected to be about $10,000. While a given kit may be applied with minimal changes to several engine families, a separate low-mileage certification test is required for each kit sold for each engine family. We first examine costs for light-duty vehicles, and then consider the costs for the smaller heavy-duty vehicle segment.

6.2.1 Estimation of Total Costs for Low-mileage Tests for Light-duty Vehicles

The number of tests for light-duty vehicles, and thus the total costs, depends on how many engine families for which the kit makers decide to offer kits. The number of potential engine families is quite large, if there are no constraints on a kit maker adding additional families. For example, ANGI has offered (and has certified) kits for over 100 different engine families in the State of Colorado. If every kit maker and engineered converted offered kits for 100 different engine families, the total number of low-mile tests would range into the thousands.

ICF considers it unrealistic to assume that all kit makers would certify kits for all possible engine families if a low-mile test were required. The reason is three-fold:

1. Firms will not spend $10,000 on a test for a given engine family, in addition to the costs of calibrating the kit for the particular needs of that engine family, if they cannot recoup that investment by charging more for each kit sold for that family.

2. Not every engine family offers the same sales potential for kit makers. The lowest-volume engines may provide such low kit sales that recouping a $10,000 testing investment would require a prohibitive increase in the cost of the kit.

3. Due to their size or other operational or technological constraints, some families such as diesels or those intended for subcompacts are not good candidates for conversions.

This reasoning is illustrated by Exhibit 6-1, "Distribution of Sales by Engine Family." The chart is based on sales share data for heavy-duty diesel engines, though the concept it illustrates is likely to hold for light-duty engine as well. The chart shows the sales shares for
all but the highest-selling engines. The engine families are ranked by sales share, with
the lowest-selling engines (e.g., numbers 60 through 80) at the right. Sales shares decline
very regularly; in fact, the assumption that each additional engine family sells about six
percent less than the one before it seems reasonable. This pattern is illustrated by the
regression line superimposed on the bars.

The point that can be made with the bar chart is as follows: firms can ensure that they
have sales great enough to pay for their low-mile tests and calibration costs if they
concentrate largely on the high-volume engine families to the left, and decline to test kits to fit
the majority of the low-volume families to the right.

ICF has made some estimates of the costs per conversion that kit makers would have
to pass along to cover the costs of low-mile tests. It was assumed that

♦ A low-mile test costs $10,000;
♦ Calibration costs (that is, the development costs to ensure that the kit/engine
combination will work and will meet emissions standards) will cost an additional
$20,000 per kit, and
♦ Both costs could be amortized over five years at a 10 percent discount rate; a
total of $30,000 spread over five years at a 10 percent discount rate equals about
$8,000 per year.

If sales for a particular kit maker's kit for a particular engine family are too low, it will
become impossible to pass on the full costs of the calibration and testing. For this analysis,
we are assuming that this threshold will come at the point where the per-kit cost of the test
and the development costs is about $20.

To cover a total cost of $8,000 per year without exceeding $20 per unit would require
sales of 400 units per year. This sales volume will be easily exceeded by the larger
manufacturers for the best-selling engine families, assuming fairly large total numbers of
conversions. For less popular engine families, and for small manufacturers whose conversion
kits will have more limited market penetration, sales of an individual kit could easily drop
below 400 units per year.

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35 Gaseous-fueled versions of the best-selling engine families will probably be offered by OEMs,
and so do not represent an attractive market for converters in the long run. Even though it is
believed that OEMs will offer dedicated CNG vehicles for some of the higher sales engine
families, there will still be many engine families for medium to high sales volume for which kits
will be offered.

36 Conversation with Christopher Weaver, EF&EE.
Exhibit 6-1

DISTRIBUTION OF SALES BY ENGINE FAMILY

Ranked in Order of Sales, Not Including Top Sellers

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Curve fit to data
There is no way to make solid predictions at this time as to how many kits could be offered that would sell more than 400 units per year. ICF has developed a simple methodology, however, based on plausible assumptions, that generates estimates of the number of kits with sales of at least 400 units as a function of total sales of conversion kits. The methodology makes the following assumptions about the distribution of sales:

♦ Sales of conversion kits are limited to the 70 most popular fleet engine families, not counting a handful of the top selling families, for which less expensive factory versions will be available (this assumption has only a small effect on the results);

♦ Sales of conversion kits are roughly proportional to sales of the engines themselves, meaning that popular engines will offer the greatest conversion kit sales potential;

♦ Sales of conversion kits (by all kit makers and engineered converters) across engine families are distributed so that sales of kits for any given engine family will be about six percent more than the sales for the next highest-selling engine family (estimated from Exhibit 6-1). In other words, if the total demand for all conversion kits for the best selling engine family equals 3,000, then the demand for the second-best selling family will equal six percent less or 2,820; demand for the third-best seller will be about 2,650, and so on.

♦ For any given engine family, sales will be divided as follows: a third of sales will go to the largest firms; just under half will go to relatively small firms; and the remainder (about a fifth) will go to the smallest firms.

♦ There are a total of 23 kit makers and engineered converters: three large; ten relatively small; and ten very small firms (based on the current size distribution of firms).

♦ Each firm will offer at most one kit for a given engine family; thus, there will be no more than 23 kits certified for each engine family.

♦ If total sales for an engine family are insufficient to provide all 23 sellers with sales of 400 per year (taking into account the assumption that each size group's share of the sales is limited), then some firms will decline to offer kits (that is, drop out of the sales competition) for that engine family. Enough firms are assumed to drop out of competition for each engine family to provide sales of at least 400 for each firm still offering a kit for that family. For example, if total sales for a family are assumed to be 2,200, and the smallest firms split 22 percent of the total, then the total share of the smallest firms will be 484. This will be enough for one very small firm to have sales of 400, but not enough for more than one. It is assumed, then, that only one very small firm will offer a kit for this engine family. A similar calculation is made for large and moderately small firms, yielding an estimate of the total number of kits offered for that family.

Applying this methodology yields a relationship between the total number of conversion kits sold for which federal low-mile tests are needed and the total number of engine families.
for which kits are offered (and tests are performed). This methodology also yields estimates of the average number of kits offered (and tests performed) by firms in different size classes.

The exhibits show the result of applying this methodology for varying levels of total conversion kit sales. The levels of 35,000 and 150,000 highlighted in the exhibit are related to the sales for the federal CFF program and the total number of conversions (not counting the California clean fuel fleet program) anticipated for the year 2000.

It is difficult to attribute numbers of tests and total costs to the Federal CFF standards as opposed to the Gaseous Fuels standards, in part because kits that have been certified under the CFF program can presumably be used to certify vehicles under the Gaseous Fuels program as well. In this report, ICF calculates impacts as though the Federal CFF program is introduced first, and imputes the costs of the tests generated by the annual CFF sales (about 35,000 per year in 2000) to the Federal CFF program. ICF then attributes to the Gaseous Fuels program all of the costs of the additional low-mile emission tests that manufacturers would choose to perform in light of the additional conversions demand due to the state clean air initiatives and the economically driven demand (an additional 115,000 conversions per year, for a total of about 150,000 conversions in 2000).

### Exhibit 6-2

**Low Mile Tests for Light-Duty Vehicles Per Firm as a Function of Total Sales**

<table>
<thead>
<tr>
<th>Total Annual Sales</th>
<th>Total Number of Low-Mile Tests</th>
<th>Tests per Large Firm</th>
<th>Tests per Small Firm</th>
<th>Tests per Very Small Firm</th>
</tr>
</thead>
<tbody>
<tr>
<td>35,000</td>
<td>74</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>45,000</td>
<td>101</td>
<td>11</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>60,000</td>
<td>137</td>
<td>15</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>90,000</td>
<td>204</td>
<td>21</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>120,000</td>
<td>267</td>
<td>24</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>150,000</td>
<td>323</td>
<td>27</td>
<td>16</td>
<td>8</td>
</tr>
</tbody>
</table>

Exhibit 6-2 shows that, because the Federal CFF standards will generate conversion sales of just over 35,000 light-duty vehicles per year in 2000, kit makers and engineered converters are likely to perform about 74 low-mile tests: eight per large firm, three per small firm, and two per very small firm. Because the total annual sales of non-California conversions are projected to total 150,000 (including the Federal CFF demand, non-California state-driven demand, and economically driven demand), kit makers and engineered converters are projected to perform a total of 323 low-mile tests: 27 per large firm, 16 per small firm, and 8 per very small firm. The incremental number of tests attributable to the Gaseous Fuels program is the difference between the total number of tests and the tests for
the Federal CFF program: 249 incremental tests in all; 19 per large firm; 13 per small firm; and 6 per very small firm.

In spite of limited coverage by each seller, choices by consumers will be affected to a very small degree only. First, even if only a fraction of all engine families are covered by any one kit maker, most of the total sales volume will be covered because kit makers will concentrate on the best-selling engines. Second, because there are 15 competing kit makers (in addition to eight engineered converters), kits for virtually all engine families are likely to be offered by at least one kit maker as the competitors seek "niches" to exploit.

6.2.2 Estimation of Total Costs for Low-mileage Tests for Heavy-duty Vehicles

Testing costs will be increased somewhat by the need to conduct low-mile tests for heavy-duty vehicles. The heavy-duty conversion market will be much smaller than the light-duty market, so the total costs for low-mile testing for this segment will almost certainly be much smaller. In recognition of the smaller size of this segment, ICF has not developed a separate methodology for estimating numbers of tests. Rather, ICF has used EPA's estimate that there will be 10 low-mile tests in all to cover the 1,500 heavy-duty conversions for the federal CFF program per year by the year 2000. These ten tests equal about an eighth of the 75 tests for light-duty CFF vehicles. For simplicity, ICF is assuming that tests for heavy-duty vehicles will also represent an eighth of the light-duty tests done for the Gaseous Fuels regulations. Thus, because there are projected to be 249 tests for light-duty vehicles under the Gaseous Fuels programs, ICF estimates that there will be roughly 30 tests for heavy-duty vehicles. Adding these 30 tests to the 10 tests for the CFF program yields an estimated total of 40 low mile tests for heavy-duty vehicles.

ICF assumes, again for simplicity, that the low-mile tests for heavy-duty vehicles are distributed across firms in the same proportions as the tests for light-duty vehicles. Tests for each size of firm are assumed to increase by about one eighth; for the CFF program, the number of tests is assumed to go up by one for a model large firm, one for a model median small firm (a slight exaggeration), and none for a model very small firm. Similarly, for the gaseous fuels program, the number of heavy-duty low miles tests are assumed to be two per model large firm, one per model median small firm, and one per model very small firm. These increased tests, and increased costs, are incorporated into the tables that follow.


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Exhibit 6-3
Low Mile Tests Costs, Light and Heavy-duty Vehicles Combined

<table>
<thead>
<tr>
<th>Program</th>
<th>Total Cost of Low-Mile Tests</th>
<th>Costs per Large Firm</th>
<th>Costs per Small Firm</th>
<th>Costs per Very Small Firm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal CFF</td>
<td>$ 840,000</td>
<td>$ 90,000</td>
<td>$40,000</td>
<td>$20,000</td>
</tr>
<tr>
<td>Gaseous Fuels</td>
<td>2,790,000</td>
<td>210,000</td>
<td>140,000</td>
<td>70,000</td>
</tr>
<tr>
<td>Total</td>
<td>3,630,000</td>
<td>300,000</td>
<td>180,000</td>
<td>90,000</td>
</tr>
</tbody>
</table>

6.2.3 Low-mile Test Costs Per Vehicle and Per Firm

Costs per conversion average about $6 for the industry as a whole, both for the Federal CFF vehicles and the Gaseous Fuels vehicles. Costs per conversion are projected to be somewhat smaller for the largest firms. These costs, which amount to less than half of one percent of the total cost of a conversion, are too small to affect industry sales significantly.

ICF expects that the cost of the low-mile tests can be largely passed on to the purchasers of converted vehicles. While in a competitive market a fixed cost is difficult to pass on to consumers due to the pressure to keep prices low and increase sales volumes, the aftermarket conversion industry is unlikely to be competitive enough to prevent the pass-through of testing costs. If only about 85 kits have been certified for light and heavy-duty CFF conversions, and a total of about 380 kits have been certified for both CFF and gaseous fuels conversions for the approximately 70 engine families commonly used for fleets, the choice of kits for most engine families will be sharply limited. Given limited competition among kit makers and engineered converters for any engine family, it is likely that a per-kit testing cost on the order of $6 per conversion can be passed on to purchasers.

The cost of low-mileage testing per conversion will vary across engine families, with higher costs for engine families with lower sales volumes. This tendency will be muted by market forces: numerous kit makers are likely to offer certified kits for those engine families that are popular for fleet use, while for many of the less popular engine families there will be no more than a single certified kit on the market. The reduced competition for the lowest volume engine families is likely to help kit makers spread their testing costs and reduce the competitive pressure to avoid passing on the testing costs as price increases.

Costs will not necessarily be spread evenly across firms. Exhibit 6-4 shows the distribution of costs across firms of different sizes of kit makers in comparison to profits and assets. Relative costs are expected to be similar for engineered converters as well, given that they are similar in size to the kit makers.
### Exhibit 6-4
Low Mile Testing Costs Compared to Model Kit Makers

<table>
<thead>
<tr>
<th>Number of Low-Mileage Tests</th>
<th>Median Large Kit Makers</th>
<th>Median Small Kit Makers</th>
<th>Lower Quartile Small Kit Makers</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFF</td>
<td>9</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>21</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>Total Cost per Firm</td>
<td>$300,000</td>
<td>$180,000</td>
<td>$90,000</td>
</tr>
<tr>
<td>Annualized Cost per Firm</td>
<td>$78,000</td>
<td>$47,000</td>
<td>$24,000</td>
</tr>
<tr>
<td>Cost as a Percentage of Assets</td>
<td>1.5%</td>
<td>8.2%</td>
<td>6.4%</td>
</tr>
<tr>
<td>Annualized Cost as a Percentage of Profits</td>
<td>8.1%</td>
<td>22.7%</td>
<td>17.7%</td>
</tr>
<tr>
<td>Cost per Kit Sold (Average Price Increase Needed to Recover Costs)</td>
<td>$3.96</td>
<td>$5.94</td>
<td>$5.94</td>
</tr>
</tbody>
</table>

Source: EPA and ICF Analysis

Overall, the comparisons shown in Exhibit 6-4 suggest that, while financing the initial costs of the tests will be slightly less burdensome for the largest firms in the industry than for the small firms, all sizes of firms are likely to have ample resources for conducting the tests. In addition, costs per kit are small in comparison to the total cost of the typical conversion, and are relatively constant across firm sizes. Given that the small and relatively uniform costs of testing can probably be passed through to purchases in the prices of the conversions, the low-mile tests are unlikely to have a permanent impact on the financial strength of the firms in the industry.

### 6.3 Tailpipe Tests for CFF Vehicles

Tail-pipe tests to ensure that a certified kit was installed correctly are likely to be an important element of the industry’s marketing and quality assurance strategy, even if they are not required by law. Costs are estimated to fall between $5 and $25 per vehicle at an I&M
test station. Where test stations are available, this cost will not have a significant impact on
the market for several reasons. First, the tests add value to the conversion in most cases
(that is, where the vehicle can be certified as a clean-fuel vehicle after it has been tested).
Second, the costs appear to be minor—less than one percent of the total cost of the
conversion. Given that ICF estimates the demand elasticity for gaseous conversions to be
moderately low (between -1 and -2), there will an impact on sales of less than two percent,
which will be insignificant in a growing market.

For the small segment of the industry that is devoted to CFF kit installations but is
outside of the non-attainment areas where test stations are generally available, however, it is
somewhat more difficult to estimate the impacts of the testing requirement. On one hand, it
seems likely that vehicles to be converted to meet the clean fuel fleet standards will be used
in areas with I&M stations available, even if these stations are not available where the
conversion is performed. Thus, the purchasers would be able to have these tests performed
in their city as a final condition of delivery, and the need to have the tests performed at an
I&M station would not have a greater impact on small entities without access to sophisticated
testing equipment. In addition, because kit suppliers are likely to have a strong interest in the
correct installation of their kits (to preserve their reputation for quality), they are likely to
require their installers to have available the equipment needed to ensure that the conversions
have been performed correctly. As described in Chapter 5, this means that installers have to
have available a dynamometer and equipment to analyze exhaust gases.

On the other hand, to the extent that converters will need to test and possibly adjust
the vehicles they have converted before releasing them to the fleet owners, small converters
would be at a disadvantage if they could not afford testing equipment equivalent to that
provided by a high-technology I&M station. For a volume of 1,000 vehicles per year, high-
technology transient tests have been estimated to cost a total of $57.05 per vehicle for
equipment alone; for smaller volumes (e.g., 300 clean-fuel vehicles) this cost would become
prohibitive (an added $200 or more). These smaller converters might be limited to serving the
market for non-clean fuel fleet vehicles. EPA does not expect, however, that tail-pipe testing
will demand equipment that is more sophisticated than the installers will already have
available.

6.4 Summary of Estimated Regulatory Costs

This section summarizes the regulatory costs presented in the previous sections in two
ways. First, it presents per-vehicle regulatory costs for the model firm kit makers. Second, it
presents estimates of annual program costs in the year 2000 for the proposed Clean Fuel
Fleet and Gaseous Fuels regulations.

Exhibit 6-5 summarizes the per-vehicle regulatory costs for kit makers. The
methodology used in developing these estimates was presented earlier in this chapter and,
therefore, will not be stated in detail here. As shown in this exhibit, per-vehicle costs for the
CFF program are approximately $20 for all three model firms, including tailpipe test costs. As
explained earlier, we have assumed that only larger kit makers will undertake emissions tests
to prove a technology, that each large firm will, on average, conduct two emissions tests, and
that these costs will be spread evenly over both CFF and Gaseous Fuels kit sales. This
# Exhibit 6-5

**Summary of Per-Vehicle Compliance Costs for Kit Makers**

($ per Vehicle)

<table>
<thead>
<tr>
<th></th>
<th>Clean Fuel Fleet Program</th>
<th></th>
<th>Gaseous Fuels Program</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large Co.</td>
<td>Median Small Co.</td>
<td>Lower Quartile Small Co.</td>
<td>Large Co.</td>
</tr>
<tr>
<td>Emission Test</td>
<td>2.11</td>
<td>0</td>
<td>0</td>
<td>2.11</td>
</tr>
<tr>
<td>Low-Mile Test</td>
<td>4.75</td>
<td>5.28</td>
<td>5.28</td>
<td>3.69</td>
</tr>
<tr>
<td>Tailpipe Test*</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>21.86</td>
<td>20.28</td>
<td>20.28</td>
<td>5.80</td>
</tr>
</tbody>
</table>

* If required.
results in per-vehicle emission test costs of $2.11 for large firms and zero for other firms. CFF low-mile tests will result in roughly comparable per-vehicle costs for small and large kit makers ($4.75 versus $5.28); small firms have lower sales over which to spread test costs, but may choose to minimize testing costs by performing fewer low-mile tests. Per-vehicle tailpipe costs are approximately $15. It should be noted that kit makers may not pay for the tailpipe test if the kit is installed by another company or if the customer pays for it directly. Nevertheless, we have included it because it is a per-vehicle regulatory cost.

Per-vehicle costs from the Gaseous Fuels regulations are approximately one-quarter the costs of the Clean Fuel Fleet program. This difference is primarily due to the fact that the Gaseous Fuels regulations do not require tailpipe tests, although many companies may opt to conduct them anyway to verify the quality of their work. Per-vehicle emissions costs are assumed to be the same as for the Clean Fuel Fleet program ($2.11 for the large model firm). Low-mile test costs per-vehicle for the model firms are similar for both programs. While sales will be higher under the Gaseous Fuels program than the CFF program, all model firms are projected to incur more low-mile testing costs under the Gaseous Fuels program in an effort to secure a larger share of this market.

Exhibit 6-6 presents estimated total program costs for the year 2000. To calculate these estimates, we multiplied the test cost annualized over a 5-year period by the number of each test required under the two regulations. As shown in this exhibit, annualized program costs for each regulation are approximately $830,000. However, the portion of costs attributable to each test vary significantly between the two programs. If tailpipe tests are required, their costs will fall only on the CFF program. The larger sales of the Gaseous Fuels program will result in larger total costs for the emissions and low-mile tests.

Exhibit 6-6
Summary of Estimated Total Program Costs
(Annual Cost for the Year 2000)

<table>
<thead>
<tr>
<th></th>
<th>Cost per Test</th>
<th>Clean Fuel Fleet Program</th>
<th>Gaseous Fuels Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Test</td>
<td>$80,000</td>
<td>$31,400</td>
<td>$95,200</td>
</tr>
<tr>
<td>Low-Mile Test</td>
<td>$10,000</td>
<td>$221,600</td>
<td>$736,000</td>
</tr>
<tr>
<td>Tailpipe Test*</td>
<td>$15</td>
<td>$577,500</td>
<td>$0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$830,500</td>
<td>$831,200</td>
</tr>
</tbody>
</table>

* If required.

Tailpipe costs are estimated to be between $5 and $25; we have used $15 for simplicity.
6.5 Cut-off Points

EPA has considered proposing a requirement for all Clean Fuel Fleet conversions to be tested, and has also considered providing entities performing 300 or fewer conversions per calendar year (and who do not have access to an i/M facility) with an exemption from these testing requirements. ICF’s judgment is that the proposed 300 conversion cut-off is not unreasonable for the following reasons.

First, the proposed cut-off is at a level where it will help the smallest installers but will not be a blanket exemption for the majority of the industry (see Exhibit 3-4). Second, the proposed cut point is financially plausible. Installation and emissions testing equipment costs are approximately $50,000. If amortized over five years, at a 10 percent discount rate, equipment costs amount to about $13,000 per year. If a company performs 300 conversions per year, costs would amount to approximately $45 per conversion - a relatively small fraction of the total cost for a conversion. If the exemption were placed considerably lower (e.g., 50 conversions per year), however, the cost of testing equipment becomes prohibitive ($300 per conversion).

Moreover, the number of companies using the exemption is not expected to be very sensitive to the cut-off for the following reasons:

♦ The more prominent kit makers require emissions testing to assure the quality of the installation. Thus, many installers will perform CO emissions tests regardless of the federal exemption.

♦ The fact that installation of kits in accordance with the Gaseous Fuels NPRM necessitates the use of certain equipment (e.g., a dynamometer) means that almost all installation companies will have adequate test equipment to perform CO emissions tests.

♦ Even if the cut point were set too high, many companies would opt not to use the exemption because it is a good selling point to show the customer that a vehicle has been fully tested and meets the required standards.

♦ Setting the cut-off much lower than 300 conversions (e.g., fewer than 100) would make the exemption irrelevant, because companies with very low volumes are unlikely to be competitive in this industry.

♦ There are expected to be relatively few installation companies outside non-attainment areas.

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39 Section 5.2 of our report.

Final Report * * * September 26, 1992
Appendix A
Glossary of Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFV</td>
<td>Alternative fuel vehicle.</td>
</tr>
<tr>
<td>Closed Loop</td>
<td>Advanced fuel metering control in which, through the use of an oxygen sensor and microchip processor, the air/fuel ratio of a vehicle is constantly and dynamically controlled to give optimal performance.</td>
</tr>
<tr>
<td>CNG</td>
<td>Compressed natural gas, mainly methane (CH₄).</td>
</tr>
<tr>
<td>Dual-Fueled</td>
<td>Refers to an engine capable of operating on two separate fuels, one a traditional fuel such as gasoline or diesel fuel, and the other an alternative fuel, such as CNG or LPG.</td>
</tr>
<tr>
<td>LPG</td>
<td>Liquified petroleum gas, mainly propane (C₃H₈).</td>
</tr>
<tr>
<td>NGV</td>
<td>Natural gas vehicle.</td>
</tr>
<tr>
<td>Non-attainment Area</td>
<td>Geographic area officially designated as exceeding federal air quality emissions standards.</td>
</tr>
<tr>
<td>NOₓ</td>
<td>Oxides of nitrogen</td>
</tr>
<tr>
<td>OEM</td>
<td>Original equipment manufacturer.</td>
</tr>
<tr>
<td>Open Loop</td>
<td>Carburetion, in which the carburetor is throttle controlled.</td>
</tr>
<tr>
<td>Reformulated gasoline</td>
<td>Conventional gasoline with one or more components changed or modified to reduce emissions levels, typically benzene, aromatics, lead, detergents, and oxygen content, among other components.</td>
</tr>
</tbody>
</table>
Appendix B
Assessment of Demand Elasticity

No direct empirical measures of the sensitivity of demand for conversions to changes in their cost (i.e., the price elasticity of demand) are available. As a general rule, demand elasticity for a product is higher if there are more and better substitutes for that product. Thus, we can expect that demand elasticity for gaseous-fueled vehicles will be higher if they are in competition with both electric vehicles and with reformulated gasoline fueled vehicles, than if their competition were limited to electric vehicles. Similarly, demand elasticity is probably much higher for a single supplier of gaseous vehicle conversions or kits than for the industry as a whole, because a single supplier has many more competitors offering good substitutes than does the entire industry.

Though there are no empirical estimates of demand elasticity for the conversion industry, it is possible to predict an approximate range for the elasticities on the basis of the underlying economics and by drawing on studies of closely related industries. This appendix presents the methodology used to project demand elasticities for firms in the gaseous fuel conversions in competition with reformulated gasoline fleet vehicles; with electric vehicles; and with other gaseous fuel converters. All of these estimates are subject to considerable uncertainty, and all could be improved with additional data and analysis.

Demand Elasticity for Gaseous Fuel in Competition with Gasoline

A rough estimate of the sensitivity of gaseous-fueled vehicle sales to changes in their prices can be made by estimating the fraction of the potential fleet for which a given price increase would eliminate the cost-effectiveness of changing fuels. For example, there might be 100,000 vehicles for which the economic benefits of CNG outweigh the costs, but only 90,000 vehicles for which the benefits outweigh the costs by at least $100. In this case, we can predict that a $100 increase in price will make a CNG conversion uneconomic for ten percent of the potential customers—that is, for the 10,000 vehicles for which the net benefits of a CNG conversion were less than $100 before the price went up.

To estimate the percent of vehicles for which a $100 increase in conversion costs would determine whether or not a CNG conversion would be cost effective, ICF used data on the per-mile fuel cost advantage of CNG compared to gasoline, and the distribution of miles traveled per year by cars and vans in fleets. Because of CNG’s price advantage of about 50 cents per gallon equivalent (or two cents per mile for a vehicle that gets 25 miles per gallon), a CNG conversion is more cost-effective if the vehicle is used intensively. At a savings of two cents per mile, CNG provides an extra $20 per year for a vehicle that is driven 1,000 miles more per year. At a real discount rate of 10 percent per year and a vehicle life of eight years, an extra $20 per year has a present value of just over $100. Thus, increasing the price of a conversion by $100 will raise the threshold at which CNG becomes cost-effective by 1,000
miles traveled per year: if a CNG conversion had been economical for all vehicles used more than 25,000 miles per year, a price increase of $100 means that CNG will be economical only for vehicles used more than 26,000 miles per year.

Two questions remain: (1) where is the threshold, in terms of miles travelled per year, at which a CNG conversion become economical at present; and (2) what percentage of fleet vehicles above that threshold are within 1,000 miles per year of the threshold? By answering these two questions, it is possible to estimate the percentage of the potential conversion market that might be eliminated by a $100 price increase.

About half of fleet cars (54 percent) are driven an average of 60 or more miles per day, or more than about 22,000 miles per year according to a report on electric and hybrid vehicles by William Hamilton (Table 2.3 of Hamilton, p. 30). ICF assumes that the threshold at which CNG conversions become cost-effective is at that point or higher, given that a conversion is relatively expensive, and therefore cannot be justified on economic grounds for vehicles that are used sparingly. The data presented by Hamilton (p. 30) show that the usage range of 60 to 90 miles per day, or about 22,000 to 33,000 miles per year, encompasses about 22 percent of all fleet vehicles. A range of 1,000 miles per year (e.g., between 22,000 and 23,000 miles per year, or one-eleventh of the range from 22,000 to 33,000 miles per year) probably encompasses, therefore, about two percent of all fleet vehicles (one-eleventh of 22 percent). Thus, raising the economical conversion threshold by 1,000 miles per year (through a $100 price increase) probably reduces the stock of potential conversions by about two percent of the total population of fleet vehicles.

If half of all fleet vehicles are above the threshold for conversion, a change in demand of two percent of the all fleet vehicles would equal four percent of all potential conversions. Similarly, if only a fourth of all fleet vehicles are above the threshold (as would be the case if the threshold were somewhat above 33,000 miles per year), cutting demand by two per cent of the fleet would amount to cutting demand for conversions by eight percent.

If a $100 price increase on a $2,500 conversion, which is a four percent price increase, cuts the quantity demanded by four percent, the demand elasticity is equal to -1. Similarly, if the four percent price increase leads to an eight percent drop in quantity demanded, the elasticity equals -2.

**Estimating the Elasticity of Demand Facing a Single Supplier**

If the price were increased by $100 only one supplier, instead of by all CNG converters, the elasticity would almost certainly be five to ten times larger, because the substitutes for a the products of a single supplier are much better and more numerous than the substitutes for the products of an entire industry. One indirect estimate of the demand elasticity facing a single truck engine manufacturer found an elasticity of -5, as compared to an empirical.
estimate of close to -0.5 for trucks as a whole.\textsuperscript{40} A reasonable estimate might be that a $100 price increase by a single supplier would cut potential sales by between 20 percent and 80 percent, rather than by four to eight percent. Estimates of elasticities of demand faced by individual suppliers, however, are considerably more difficult to predict, due to their dependence on the perceived differences among the products and services offered by different suppliers.

**Assessment of Elasticity for Gaseous Fueled Vehicles in Comparison to Electric Vehicles**

In situations in which gaseous fuel vehicles are in competition with electric vehicles only, a measure of demand elasticity for gaseous fueled vehicles can be inferred from a measure of the price sensitivity for electric vehicles because a decline in sales for one would imply an increase for the other. Figure 2-4 of Hamilton’s report on electric and hybrid vehicles shows the results of a survey analysis of demand for electric vehicles (EVs). It shows that a reduction of five percent in the life-cycle cost of electric vehicles relative to their competition would increase their penetration by about 15 percent of its initial value (e.g., from 47 percent to 55 percent, for an EV with a 50 mile range). As the life-cycle costs of an EV are almost $25,000 a five percent change in costs relative to other vehicle types amounts to $1,250.\textsuperscript{41} If a $1,250 change in relative costs causes a 15 percent change in electric vehicle penetration, and if electric vehicles and gaseous fueled vehicles shared the market equally at first, a $1,250 change in costs might also cause a 15 percent change in sales for gaseous fueled vehicles. Because $1,250 is 50 percent of the cost of a gaseous fuel conversion costing $2,500, the implied price elasticity is -15%/50% or -0.3. This order-of-magnitude estimate is consistent with the prediction that elasticity will be low if substitutes are few and imperfect.


\textsuperscript{41} Table 3-2 “Estimated Life-cycle Costs for Electric and Gasoline Cars,” p. 3-9 of Methodology for Analyzing the Environmental and Economic Effects of Electric Vehicles: An Illustrative Study, ICF Inc., prepared for E.S. EPA, Office of Mobile Sources, September 1991. Present value of annualized costs of $4,882, assessed at a discount rate of 12 percent over eight years, equal $24,252.