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16. Abstract

Increased emphasis on energy efficiency and air quality has resulted in a number of state and federal initiatives examining the use of alternative fuels for motor vehicles. Texas' program for alternate fuels includes compressed natural gas (CNG). Based on an analysis of 30-year life-cycle costs, CNG is a cost-effective option for high-mileage taxi operations. High mileage is defined as at least 83,586 miles (134,573 km) for a fleet of 5 taxis, 35,769 miles (57,588 km) for a fleet of 25 taxis, and 30,193 miles (48,611 km) for a fleet of 50 taxis. The largest fleet (50) generates an Internal Rate of Return on investment of 30 percent; 22.5 percent is realized for the medium (25) fleet, and 11 percent for the small (5) fleet. Availability of original equipment manufacturer (OEM) dedicated natural gas vehicles is vital to the future success of CNG taxi operations. OEM vehicles offer important efficiency gains needed to justify the purchase of CNG vehicles.

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COST-EFFECTIVENESS ANALYSIS OF CNG URBAN TAXI OPERATIONS

by

Mark A. Euritt

Oil Overcharge Report Number 3003-1F

Contract Number 502XXF3003

Energy Savings From an Urban CNG-Operated Taxi Company

conducted for the

Texas Department of Transportation

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

October 1993

Implementation Statement

The purpose of this project is to evaluate the economic feasibility and energy savings of an urban taxi CNG fleet. Due to the cancellation of the project, the life-cycle cost/benefit analysis model serves as the basic tool for evaluation. This model, as presented in this report, can be used by fleets to evaluate the cost-effectiveness of CNG for their operation. The model allows for inputs to be adjusted by the user.

Prepared in cooperation with the Texas Department of Transportation, Oil Overcharge Program.

Disclaimers

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented within. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

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BIDDING OR PERMIT PURPOSES

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Contract Supervisors

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Mark A. Euritt

October 1993

Abstract

Increased emphasis on energy efficiency and air quality have resulted in a number of state and federal initiatives examining the use of alternative fuels for motor vehicles. Texas' program for alternate fuels includes compressed natural gas (CNG). Based on an analysis of 30-year life-cycle costs, CNG is a cost-effective option for high-mileage taxi operations. High mileage is defined as at least 83,586 miles (134,573 km) for a fleet of 5 taxis, 35,769 miles (57,588 km) for a fleet of 25 taxis, and 30,193 miles (48,611 km) for a fleet of 50 taxis. The largest fleet (50) generates an Internal Rate of Return on investment of 30 percent; 22.5 percent is realized for the medium (25) fleet, and 11 percent for the small (5) fleet. Availability of original equipment manufacturer (OEM) dedicated natural gas vehicles is vital to the future success of CNG taxi operations. OEM vehicles offer important efficiency gains needed to justify the purchase of CNG vehicles.

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Summary

This report summarizes the results of an analysis of compressed natural gas (CNG) for urban taxi operations. Recent experiences with CNG are reviewed. The projected was intended to monitor an actual urban taxi operation; however, the project was canceled prior to this activity. In its place, a cost-effectiveness model for CNG was calibrated to evaluate urban taxi operations. Based on the analysis, CNG is cost-effective for high-mileage fleets, depending on fleet size. Public refueling is a viable option for fleets with fewer than 10 vehicles, and for those vehicles that average around 85,000 miles (136,850 km) per year.

I. INTRODUCTION

OVERVIEW

A new era has dawned on the transportation system. In the past, transportation primarily focused on providing accessibility for growing mobility needs. The transportation system was, and continues to be, vital to the economic growth of the country. During the last decade, the challenge was to address the dramatic growth in urban congestion with a resource base ill-equipped to keep pace. Numerous strategies and methods were enacted to address this challenge. For the future, transportation decision-makers will continue to battle this problem, but according to a new paradigm. Solutions to future transportation problems will not only address mobility needs, but also national security and environmental needs. In addition to promoting economic growth, transportation also affects other national and state policy objectives.

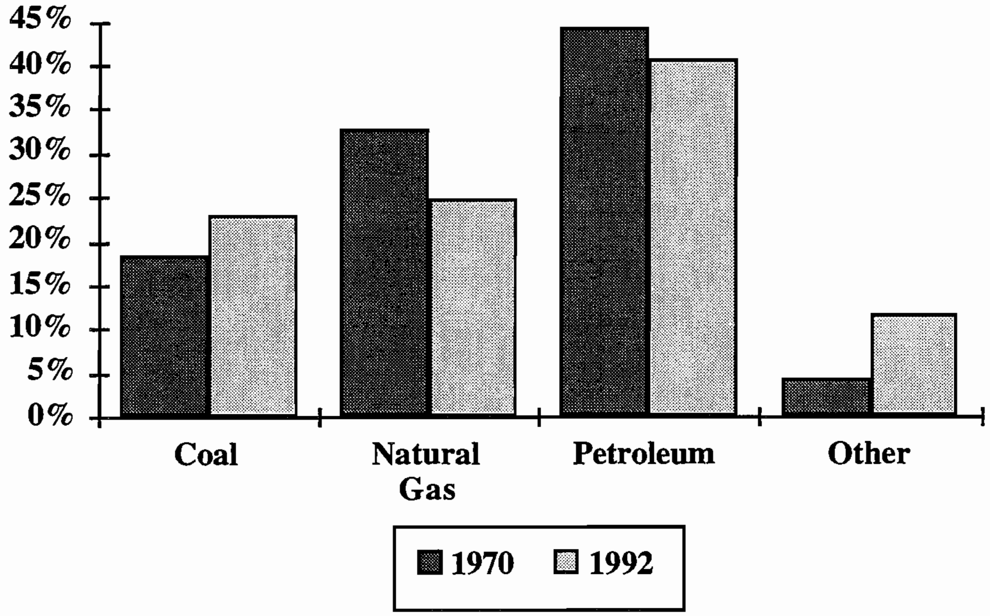
Transportation and Energy

The U.S. is a major energy consumer and the world's largest consumer of petroleum. The U.S. consumed nearly 33.5 quadrillion Btu's (quads) of petroleum in 1992 (EIA, 1993). As demonstrated in the 1970's and 1980's, this dependence on petroleum has serious implications for national security. The vulnerability to unstable foreign petroleum sources has led to a reduction in petroleum use as a percentage of total U.S. energy consumption, as shown in Figure 1-1.

Despite this trend, total petroleum consumption has increased from 29.52 quads in 1970 to 33.47 quads in 1992 (EIA, 1993). With the exception of natural gas, all sources have increased in use since 1970, as shown in Figure 1-2.

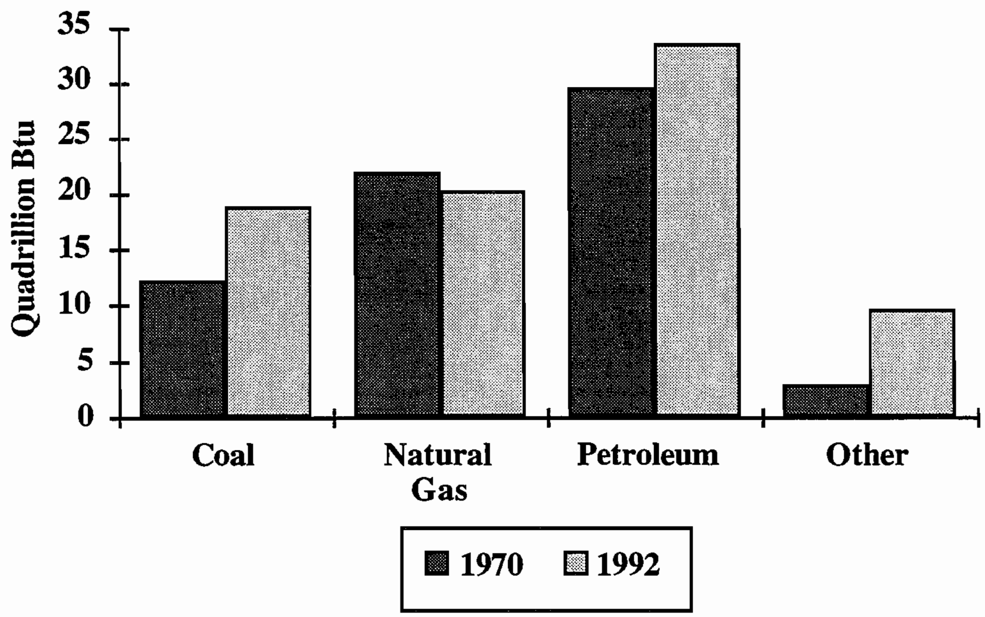
U.S. oil consumption comes into clearer focus when examining sector use. As illustrated in Figure 1-3, the residential, commercial, and electric utility sectors have reduced their consumption of petroleum since 1970, while the industrial sector has seen a small increase. On the other hand, the transportation sector's consumption of petroleum has risen dramatically from 7.78 million barrels/day in 1970 to 10.93 million barrels/day in 1993, a 40 percent increase. Within the transportation sector, petroleum accounts for 97 percent of total energy consumption (EIA, 1993). By mode, highways account for nearly 75 percent of total energy consumed in the transportation sector (Davis and Strang, 1993). Clearly, future efforts to address energy security must include

Figure 1-1
Distribution of U.S. Energy Consumption



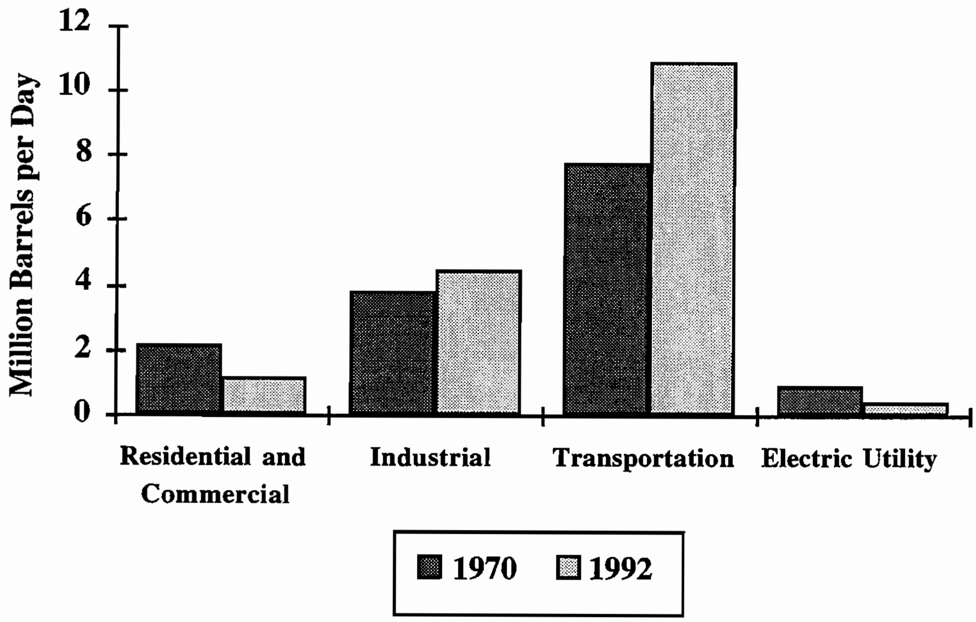
Source: EIA, 1993.

Figure 1-2
U.S. Energy Consumption



Source: EIA, 1993.

Figure 1-3
U.S. Petroleum Use by Sector



Source: EIA, 1993.

serious discussions about the U.S. transportation system and more specifically the highway mode.

Transportation and the Environment

One of the most pressing issues during the last decade has been concern over environmental degradation. Significant debate has taken place over procedures to improve air, water, land-use quality, and global warming. Within the area of air quality, the U.S. Environmental Protection Agency (EPA) has been charged with monitoring urban emissions through establishing National Ambient Air Quality Standards (NAAQS) for six criteria pollutants: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3),[1] particulate matter (PM-10), and sulfur dioxide (SO_2). All of these pollutants have deleterious effects on health. While the transportation sector has made significant progress in reducing emissions, the transportation sector remains a significant contributor to total emissions. As illustrated in Table 1-1, the transportation sector remains the primary source of CO emissions, and is the number two contributor for all other regulated emissions, except SO_2. Future efforts to improve air quality must continue to include the transportation sector.

[1] Ozone formation is regulated through the control of volatile organic compound (VOC) emissions.

Table 1-1
Percentage of Regulated Emissions by Sector, 1991

Emission	Transportation	Fuel Combustion	Industrial Processes	Solid Waste & Other
CO	70.0	7.5	7.6	14.9
Pb	32.6	9.0	44.5	13.9
NO_x	38.7	56.4	3.2	1.7
VOCs	30.1	4.0	46.5	19.4
PM-10	27.8	20.2	33.8	18.2
SO_2	4.8	79.8	15.2	0.2

Source: EPA, 1992.

FEDERAL AND STATE POLICY INITIATIVES

Because of the importance of transportation in developing sound policies for energy security and improved air quality, much attention has been directed to non-petroleum based and clean-burning alternative fuels for motor vehicles. A number of federal and Texas initiatives have been developed in the last six years that promote the use of alternative transportation fuels.

Federal Initiatives

Alternative Motor Fuel Act of 1988. The major provision of this Act was the modification of the existing Corporate Average Fuel Efficiency (CAFE) program to include the building and selling of alternative fuel vehicles. The adjustment to the CAFE program provided for fuel economy calculations based on the actual or assumed gasoline content of the fuel (The Clean Fuels Report, September 1993).[2] The Act was primarily aimed at alcohol fuels and natural gas. The Act also established a Alternative Fuels Advisory Council to report to the Interagency Commission on Alternative Motor Fuels and created the National Alternative Fuels Data Center at the National Renewable Energy Laboratory in Golden, Colorado (Deshazo et al, 1993). Finally, the law required that government-owned refueling stations for alternative fuels be opened to the general public (The Clean Fuels Report, September 1993).

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2 For compressed natural gas (CNG), the vehicle is assumed to burn 15 percent gasoline for the CAFE calculation.

Clean Air Act Amendments of 1990 (CAAA). The alternative transportation fuels provisions of the CAAA are directed towards improving air quality. Alternative fuels include various low-emitting petroleum-based fuels, such as reformulated gasoline and oxygenated fuels. Strict tailpipe emissions standards were established for all vehicles. Additionally, the Act authorized the Clean Fleets Program. Automobile manufactures are required to produce 150,000 clean fuel vehicles by 1996 and 300,000 by 1999. Starting with model year 1998, fleets with 10 or more vehicles in the serious, severe, and extreme ozone non-attainment cities are required to begin purchasing these vehicles. It is optional for fleets in marginal and moderate ozone non-attainment cities.

Energy Policy Act of 1992 (EPACT). This Act uses mandates and incentives for domestically produced alternative fuels to reduce the nation's dependence on foreign oil. With respect to mandates, EPACT requires fleets for federal, state, and fuel providers to begin purchasing alternative fuel vehicles (restricted to non-petroleum-based fuels) over a period of time. In 1996, the alternative fuel vehicle requirements may be extended to private and municipal fleets.

In addition to a Local Bus Program, an Electric Vehicle Demonstration Program, and an Alternative Fuel Research and Development Program, the Act provides incentives for purchasing alternative fuel vehicles and infrastructure development. The vehicle deductions are shown in Table 1-2 (Hitchcock, No. 1-6). This deduction applies to both factory made vehicles and after-market conversions beginning June 30, 1993, during the year the vehicle is purchased or converted. This deduction is phased out between 2002 and 2004. The vehicle tax deduction is based on the incremental cost of the alternative fuel vehicles over that of its gasoline or diesel counterpart. Between June 30, 1993 and December 31, 2004, providers of clean-fuel refueling facilities are eligible for a tax deduction of up to $100,000 for the year facilities are placed into service. This deduction also will be phased out between 2002 and 2004.

Table 1-2
Alternative Fuel Vehicles Tax Incentives

Vehicle Class/Group	Maximum Tax Deduction
≥ 26,000 lbs (11,804 kg)	$50,000
26 or more adult passengers	$50,000
10,000 - 26,000 lbs (4,504 - 11,804 kg)	$5,000
All other vehicles	$2,000
	Tax Credit
Electric vehicles	$4,000

Texas Initiatives

Senate Bill 740. SB 740 is "an act relating to the purchasing, lease or conversion of motor vehicles by state agencies, school districts, and local transit authorities and districts to assure use of compressed natural gas or other alternative fuels" (Hitchcock, No. 1-1). Alternative fuels in Texas currently include natural gas, propane, methanol, ethanol, and electricity. The law became effective September 1, 1991, for (1) school districts with more than 50 vehicles used for transporting children, (2) state agencies with more than 15 vehicles, excluding law enforcement and emergency vehicles, (3) all metropolitan transit authorities, and (4) all city transit departments. The law requires all new vehicles purchased for the above groups to be capable of operating on an alternative fuel. In addition, these organizations must meet the alternative fuel conversion requirements shown in Table 1-3. The conversion to 90 percent is contingent on a ruling by the Texas Air Control Board (TACB) that the program has been effective in reducing total annual emissions. Compliance may be accomplished through the purchase of new vehicles, the conversion of existing vehicles, or by leasing the necessary vehicles.

Table 1-3
SB 740 Conversion Schedule

Date	Percent of Fleet
9/1/94	30%
9/1/96	50%
9/1/98	90%

An important component in the development and adoption of this legislation was the argument that utilization of alternative fuels would produce cost savings to state agencies. Accordingly, the legislation allows for a waiver if the affected agency can demonstrate that either (1) the effort for operating the alternate-fueled fleet is more expensive than a gasoline or diesel fleet over its useful life, (2) alternative fuels are not available in sufficient supply, or (3) the agency is unable to acquire alternative fuel vehicles or equipment necessary for their conversion. To date, no waivers have been granted by the Texas General Services Commission, although several studies have demonstrated that alternative fuel vehicles are not cost-effective for some public fleets (see Euritt et al, August 1992, and Euritt et al, October 1992).

Senate Bill 769. This bill, which amends the Texas Clean Air Act, is an act relating to the adoption of certain regulations to encourage and require the use of natural gas and other alternative fuels in designated federal non-attainment regions, which currently include the Houston, Dallas-Fort Worth, Beaumont-Port Arthur, and El Paso areas (Hitchcock, No. 1-1).

The organizations affected by this bill include (1) metropolitan and regional transit/transportation authorities, (2) city transportation departments, (3) local governments with 16 or more vehicles (excluding law enforcement and emergency vehicles), and (4) private fleets with 26 or more vehicles (excluding law enforcement and emergency vehicles). The implementation schedule and requirements for the first two groups are the same as SB 740 illustrated in Table 1-3. If the TACB determines that the alternative fuels program has been effective in reducing emissions, then groups 3 and 4 above will be required to convert to alternative fuels according to the schedule shown in Table 1-4. SB 769 became effective September 1, 1991.

Table 1-4
SB 769 Conversion Schedule
for Local Government and Private Fleets

Date	Percent of Fleet
9/1/98	30%
9/1/00	50%
9/1/02	90%

Senate Bill 737. SB 737 is an act relating to fuels and creation of an alternative fuels council and an alternative fuels loan program. SB 737 authorizes the creation of the Alternative Fuels Council (AFC) to oversee the Alternative Fuels Conversion Fund and promote the use of environmentally beneficial alternative fuels. The council consists of the General Land Office Commissioner, the three Railroad Commissioners, the Chairperson of the General Services Commission, and the Chairperson of the Texas Air Control Board (TACB), or designated representatives from these agencies.

The Alternative Fuels Conversion Fund is commissioned to make loans or grants for activities supporting or encouraging the use of alternative fuels. The fund is supported by designated oil overcharge funds, gifts, grants, payments made on fund loans, interest earned on the fund, and other government-approved money. The fund targets historically underutilized businesses, individuals with low incomes, institutions of higher learning, and health care facilities. In addition, government agencies, school districts, and transit authorities are automatically eligible. The loans can be for vehicle purchases, conversions, and construction of public refueling facilities (Hitchcock, No. 1-5).

Finally, SB 737 authorizes the Texas Public Finance Authority to issue bonds up to $50 million for:

- conversion of state vehicles to alternative fuels;
- construction of alternative fuel vehicle refueling stations;
- conversion of school buses;
- conversion of transit authority vehicles; and
- public-private joint ventures to develop alternative fuel infrastructure.

Bond issuance is contingent on the proposed project demonstrating energy and cost savings (Hitchcock, No. 1-5).

Senate Bill 7. This bill amends the requirements of SB 740 pertaining to school districts with more than 50 buses. SB 7 amends the implementation requirements according to the schedule shown in Table 1-5. Unlike SB 740, the 90 percent requirement in 2001 is not contingent on the TACB ruling. School districts are encouraged to meet the 30 percent requirement by 1994, although they are not required to do so. As an incentive, SB 7 gives priority to appropriated funds for conversion for school districts meeting the 30 percent mix by 1994.

Table 1-5
SB 7 Conversion Schedule
for School District Fleets

Date	Percent of Fleet
9/1/97	50%
9/1/01	90%

SB 7 also provides for more lax waiver requirements. The burden of demonstrating economic feasibility shifts from the school district to the bidder.

STUDY OBJECTIVES

As a result of the federal and state initiatives, there has been significant progress in the evaluation and use of alternative transportation fuels. This project was designed to evaluate energy savings and cost-effectiveness of compressed natural gas (CNG) for a targeted private fleet application. Previous research on compressed natural gas utilization demonstrated potential energy savings for high-mileage vehicles (see Euritt et al, August 1992). Urban taxi operations were deemed a viable candidate for analysis.

This project, funded by Texas oil overcharge funds as part of the Texas Department of Transportation's (TxDOT's) Planning and Feasibility Study Program, was guided by two principal objectives:

(1) Identify the energy savings associated with a CNG taxi operation.

(2) Identify cost implications of operating a CNG taxi fleet.

The objectives were to be accomplished by completing the following five tasks:

Task 1 - Conduct literature review of taxi company experiences with CNG.

Task 2 - Meet with gas industry representatives and equipment suppliers about participating in a demonstration project.

Task 3 - Meet with selected taxi companies to determine interest in participating in a demonstration project.

Task 4 - Conduct cost-effectiveness analysis for the taxi fleet.

Task 5 - Conduct and monitor the demonstration project.

Task 1 was completed and the findings are shared in this report. Tasks 2 and 3 were not completed due to the premature cancellation of the project. Likewise, Tasks 4 and 5 could not be completed. However, in place of the demonstration project, a cost-effectiveness model was developed to evaluate three different-sized taxi operations under various scenarios. The model and the scenarios are presented later in this report. The model can be used by most taxi companies to evaluate the cost-effectiveness of CNG. In addition, the model can be used to calculate energy savings associated with an urban taxi operation.

II. CNG AS A TRANSPORTATION FUEL

BACKGROUND

Natural gas as a transportation fuel is not new. Worldwide, over 400,000 vehicles use natural gas as a fuel (General Accounting Office [GAO], 1992). To date, U.S. utilization of natural gas vehicles has been primarily with gas industry utility vehicles. Clean air initiatives and energy security policies, however, are promoting the use of domestic energy resources, including natural gas, in motor vehicles. Future use of natural gas vehicles will be driven by vehicle operating costs.

Natural gas consists primarily of methane (CH_4). It has a boiling point of -260 °F (-162 °C), which requires storage by compression or cryogenics. On-board storage of natural gas in sufficient quantities has been one of the marketing difficulties for its wide-spread utilization as a motor fuel. Natural gas has certain advantages when used in a motor vehicle designed for its use. It has a high octane value (120), wider flammability limits, and, as a gas, better mixing properties. Engine manufacturers taking advantage of these qualities can improve the efficiency of the internal combustion engine through increased compression and leaner air/fuel ratios (USDOE, September 1992).

Natural gas, unlike other transportation fuels, does not rely on production/refinery capacity for future demand but on the existence of reserves. U.S. proven natural gas reserves, defined as recoverable according to current production techniques, amounted to 158 trillion cubic feet (Tcf) (5.2 trillion m^3) in 1992. Estimates of future annual production in the year 2010 range from 19.45 to 20.56 Tcf (638 billion m^3 to 674 billion m^3) (STEPP, 1993).

As an alternative to gasoline, compressed natural gas (CNG) has some important advantages. Its availability and low price make it a good candidate for use by fleets.

EXPERIENCES WITH CNG

The Garland Independent School District was the first school district in Texas to operate on CNG. Of the 181 buses in its fleet, 81 were converted to CNG at a cost of $389,773. Vehicles are fueled on-site primarily using slow- or time-fill during the buses' overnight parking. The station is equipped to provide 5- to 6-minute quick-fills for some vehicles during the day. Fuel savings in

1989-90 were estimated by the School District to be $91,245. In addition, they reported maintenance savings of $3,306 for fewer needed oil changes (Hitchcock, No. 3-2).

The City of Scottsdale, Arizona has been using CNG in its fleet fore more than a decade. Currently, 117 of its 500 plus vehicle fleet operate on natural gas. It savings are generated principally from the low cost of natural gas [66.2¢/gallon of gasoline equivalent (16.4¢/L)]. Based on Scottsdale's success, a number of other Arizona cities and institutions have procured natural gas vehicles, including Glendale, Tuscon, Sun City Area Transit, Arizona State University, and Pima Community College (Hitchcock, No. 3-7).

Based on the success of other school districts and Oklahoma state incentives, the Tulsa School District has developed a 24-bus pilot CNG project. Tulsa is using both time-fill and quick-fill, but unlike Garland is operating dedicated CNG buses and not dual-fuel. In conjunction with this program, the U.S. Department of Energy (USDOE) through the National Institute of Petroleum Research is conducting emissions and oil tests on these vehicles (Hitchcock, No. 3-9).

The City of El Paso, Texas, has received a $120,000 oil overcharge grant to convert 40 vehicles to dual-fuel capability. Through a partnership with a local gas company, the city is having installed a fueling station at low cost. The gas company plans to recover its contribution through increased gas sales to the city (Hitchcock, No. 3-10).

There are numerous examples of public fleets converting to natural gas. The ones presented in this report are only a small sample. However, few private companies have ventured into this area. Following are examples of two successful taxi ventures with CNG.

PRIVATE TAXI CNG OPERATIONS

Clean Air Cab Company, Washington, D.C.[1]

Clean Air Cab, a Washington, D.C.-based operation, is the only CNG-cab in America. Clean Air Cab introduced a natural gas-powered 1992 Chevrolet Caprice on Earth Day 1992, with former presidential candidate Jerry Brown as its first passenger.

The owner/operator spends most of his time educating the public about the use of natural gas as a motor fuel. "More than half of the customers who get in the cab think they are riding with a bomb," says the owner. Each rider is given literature explaining the environmental benefits of CNG vehicles and the importance of using a domestic rather than foreign energy source. Most of

[1]The contents of this section are based on phone interviews with James Doyle, owner of Clear Air Cab.

the customers are government officials, executives of environmental companies, and natural gas executives.

Washington Gas Light Company, the local utility, assisted Doyle in setting up the natural gas operation. Clean Fuels Company converted the cab at a cost $4,500 in addition to the $15,000 sales price of the new car. The CNG-powered vehicle gets the same 22 miles per gallon equivalent of gasoline (9.4 km/L) as the traditional gasoline fueled vehicle. The cab is equipped with three storage vessels holding 350 cubic feet (11 m^3) of natural gas. The vehicle is dual-fuel, but only operates on gasoline during out-of-town trips.

Refueling has been a major challenge. The only available public fueling pumps are Washington Gas Light Company's three area compressor stations located in Forestville, Rockville, and Springfield. For numerous reasons, other sites are not accessible to the general public. CNG refueling costs 65¢/gallon equivalent of gasoline (17.2¢/L). Doyle is relying on this lower fuel price to recover the cost of the conversion. He estimates 60,000 miles (96,600 km) as the pay-off for conversion. Some savings also come from less required maintenance. Most CNG vehicles can go 20,000 miles (32,200 km) between oil changes, and 75,000 miles (120,750 km) between spark plug changes, according to Washington Gas Light Company.

Based on the initial success of this first vehicle, Clean Air Cab has converted six new 1993 Chevrolet Caprices. Unfortunately, only one of the six cabs is licensed to operate in the district. The other five are garaged while the D.C. Taxicab Commission debates whether to license the Clean Air Cab Company. Apparently, some of the 10 commissioners believe that Clean Air Cab is a competitive threat to the cab industry.

Besides this problem, the major obstacle to increased CNG use is the limited availability of fueling infrastructure. There is no incentive for cab companies to convert because there is no convenient place for refueling. Gas Light Company is willing to build a natural gas fueling facility for Clean Air Cab, if the fleet is expanded to 10 vehicles and if Clean Air Cab opens the station to at least 50 other vehicles. Since most existing natural gas vehicle (NGV) fleets have their own refueling stations, this refueling remains a major obstacle to CNG conversion.

Black Top Cabs, Ltd., Vancouver, British Columbia[2]

Black Top Cabs, a company owned by a group of individual owners, provides administrative and dispatch services to its taxi owners, and through a subsidiary, Beach View Service, provides

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[2]The contents of this section are taken from a report evaluating the Black Top Cabs experience with CNG, Final Report: Use of Natural Gas by Black Top Cabs, Vancouver, B.C. (See Reference section for complete citation.)

fueling and repairs. A long-standing agreement requires all taxi operators to purchase their fuel at the Beach View facility. Operating in Vancouver, British Columbia, Black Top Cabs launched a major CNG conversion program in 1982. A total of 128 vehicles were converted to dual-fuel CNG/gasoline. By mid-1984, the taxis were operating on natural gas 97 percent of the time.

Initially, the company experienced some oil and gas leaks with the compressor station. These have been rectified. Refueling requires slightly more time for CNG than for gasoline. All vehicles were equipped with two trunk-mounted steel storage cylinders providing a driving range of 93 to 124 miles (150 km to 200 km).

During the first two years, a number of performance and efficiency tests were conducted on the vehicles. Dynamometer tests revealed that peak power output for natural gas was about 6 percent less than that for gasoline. This was corroborated in acceleration tests that showed natural gas vehicle acceleration to 31 and 50 miles per hour (50 and 80 km/hour) taking 13 and 10 percent longer than gasoline, respectively. With respect to fuel consumption, tests revealed that, on average, 8.8 lbs (4.0 kg) of natural gas is equivalent to about 0.45 gallons (1.7 L) of gasoline.

The Black Top Cabs conversion program has been an economic success. The total costs of the conversion program are illustrated in Table 2-1.

Table 2-1
Black Top Cabs CNG Costs
(Canadian Dollars)

NGV Fueling Station	
Site Improvements	$106,000
Utility Connections	$2,000
Fueling Equipment	$419,000
Electricians and Gas Filters	$32,000
TOTAL Station	$559,000
Vehicle Conversions	
128 taxis @ $2,000 each	$256,000
TOTAL COSTS	$815,000
Federal Grants	
Fueling Station	$50,000
Vehicle Conversions	
$500 per vehicle	$64,000
TOTAL Federal Grants	$114,000
NET PROGRAM COSTS	**$701,000**

This cost was recovered during the first 13 months of CNG operations. By the end of the monitoring program, fleet savings from CNG use amounted to about $75,000 per month.

Summary

Based on the success of natural gas vehicle operations for Black Top Cabs and Clean Air Cab, taxi companies in major Texas cities were consulted to determine their interest in conducting a demonstration program. Despite the premature ending of the study, empirical data suggest that CNG taxi operations may be an economically sound operation. The next section models the use of CNG in a taxi operation on a life-cycle basis.

III. MODEL FOR ECONOMIC EVALUATION

(with Dean Taylor and Hani Mahmassani)

CONCEPTUAL FRAMEWORK

There is strong empirical evidence supporting the conversion of taxis to CNG operation. This section develops a life-cycle model for evaluating the cost-effectiveness of CNG taxi operations for private and public refueling.

As outlined in the first section, there are important social advantages to using an alternative fuel like natural gas. However, for a private operator, these social advantages are externalities. They will not enter into the economic decision until mechanisms are developed to include social costs into the cost of transportation. The fleet operator is concerned with the economic costs of operating his/her vehicles. Natural gas, as a transportation fuel, will be used only if it results in savings to the operator. A life-cycle cost/benefit analysis is the appropriate method for examining cost-effectiveness. Moreover, only the incremental differences between the CNG operation and gasoline operation need to be analyzed.

Natural Gas Benefits

The primary benefit of consuming natural gas is that it is cheaper, on a gallon (liter) of gasoline equivalent basis, than gasoline. This is the major savings benefit for CNG operation. Additionally, theoretical evaluation, as well as anecdotal evidence, suggests reduced maintenance costs for a CNG-fueled vehicle. Finally, there are income tax benefits for converting to or purchasing natural gas vehicles. As noted in the first section, a tax deduction of up to $2,000/vehicle is permitted through 2004. Moreover, a $100,000 tax deduction is provided for companies developing public refueling infrastructure. The savings associated with CNG operations are illustrated in Figure 3-1. These four benefits will form the savings basis for the life-cycle model.

Figure 3-1
Savings for CNG Operations

1. Fuel Price Differential
2. Vehicle Purchase/Conversion Tax Deduction
3. Fueling Station Tax Deduction
4. Reduced Maintenance Costs

Natural Gas Costs

The incremental costs for operating natural gas vehicles can be categorized as: (1) Infrastructure, (2) Vehicle, and (3) Operating. These cost components are discussed in greater detail in other publications (Taylor et al, November 1992, and Taylor et al, December 1991).

Infrastructure costs include all the elements for constructing a fast- or quick-fill refueling station. This includes land costs, if additional land must be purchased; station setup or preparation costs; compressor costs; storage vessel costs; dispenser costs; and dryer costs. These are the major cost components for constructing a quick-fill refueling station.

Vehicle costs include the purchase and/or conversion costs of CNG vehicles. If a new vehicle is converted to CNG, costs are basically the cost of the conversion hardware (conversion kit), the cost of the storage vessels, and the cost of labor. For an original equipment manufacturer (OEM) vehicle, these various components are added into the total price of the vehicle. We are interested only in the incremental difference between the OEM CNG vehicle and a comparable OEM gasoline vehicle.

The final cost group consists of ongoing operational costs. The station maintenance costs and power costs for operating the compressor are self-explanatory. Natural gas storage cylinders used on the vehicle require certification and recertification every three years in Texas. Since, natural gas cylinders, on a liquid volume basis, hold less fuel than gasoline, CNG vehicles require more frequent refueling. For a private operator, this means less productive wages. This cost is included in the model as Labor - fuel time loss. If additional training is necessary, then this cost should also be included. Finally, vehicles in Texas must purchase a decal to use natural gas in a motor vehicle. This decal is required in lieu of a fuel tax, and its associated costs are illustrated in Table 3-1.

Table 3-1
Texas CNG Decal Tax

	Less than 5,000 miles (8,050 km)	5,000 to 9,999 miles (8,050-16,089 km)	10,000 to 14,999 miles (16,100-24,148 km)	15,000 or more miles (24,150 km)
Class A: Less than 4,000 lbs (1,816 kg)	$ 30	$ 60	$ 90	$120
Class B: 4,000 - 10,000 lbs (1,816 - 4,540 kg)	42	84	126	168
Class C: 10,001 - 15,000 lbs (4,540 - 6,810 kg)	48	96	144	192
Class D: 15,001 - 27,500 lbs (6,810 - 12,485 kg)	84	168	252	336
Class E: 27,501 - 43,500 lbs (12,485 - 19,749 kg)	126	252	378	504
Class F: 43,501 lbs or more (19,749 kg)	186	372	558	744

Source: Sharp, 1992.

The cost components used in the life-cycle cost-effectiveness model are illustrated in Figure 3-2.

Figure 3-2
Costs for CNG Operations

1. Fueling Infrastructure
   a. Land
   b. Station Setup
   c. Compressor
   d. Storage Vessels
   e. Dispenser
   f. Dryer
2. Vehicle Capital Costs
   a. Conversion Kit
   b. Vehicle Storage Tanks
   c. Labor for Conversion
   d. OEM price differential
3. Operating Costs
   a. Station Maintenance
   b. Station Power
   c. Labor - Fuel Time loss
   d. Cylinder Recertification
   e. Natural Gas Tax Decal
   f. Additional Training

NATURAL GAS MODEL WITH PRIVATE REFUELING

This model, shown in Figure 3-3, analyzes the cost-effectiveness of compressed natural gas (CNG) as an alternative fuel for taxi operations. Basically, the model examines the benefits and costs of a CNG-fueled operation over the life-cycle of a CNG fast-fill station.[1]

All input data, calculations, and assumptions inherent in the CNG Net Present Value (NPV) model are documented. Presented first are fixed input data, followed by variable input data. Next, formulas for calculations are presented and explained where necessary. Finally, the major embedded model assumptions are laid out and explained. Throughout, variable names are used directly from the spreadsheet model. A complete list of all variables and their cell reference in the spreadsheet model is shown in Figure 3-4.

Input Data (constant)

This section presents constant input data. It is recognized that some data may be slightly different for some fleets, but it is believed that these small differences will not significantly alter the final result.

Other Factors. This section contains miscellaneous input data. They are as follows:

(1) Work.days.year - number of days the fleet is operational per year. It is assumed that taxi fleets operate 350 days per year.

(2) Fast.fill.on-board.storage - of the possible amount of natural gas, it is assumed that 92.5 percent is stored while fast-filling (IANGV, 1990). Less mass of natural gas is stored at a certain pressure as temperature increases. Since temperatures increase during fast-fill and fueling cut-off occurs at 3,000 psig (2.1 kg/mm^2), less mass [and therefore volume in standard cubic feet (scf)] is stored while fast-filling than if the tank was allowed to equalize to ambient temperature (as in slow-fill).

(3) Tank.fill.factor.3000psi - 259.67 scf (9 m^3) of natural gas is stored in one cubic foot of tank volume at 3,000 psig (2.1 kg/mm^2) at standard temperature (Christy Park, No Date).

(4) Tank.fill.factor.100psi - 7.92 scf (0.26 m^3) of natural gas is stored in one cubic foot of tank volume at 100 psig (0.07 kg/mm^2) at standard temperature (Christy Park, No Date). It is assumed that a CNG vehicle is filled when its tank pressure drops to 100 psig (0.07 kg/mm^2).

[1]This model for cost-effectiveness of CNG taxi operations is based on an earlier work by Taylor, Euritt, and Mahmassani. Details of this earlier model can be found in Taylor et al, December 1991.

Figure 3-3 (1 of 6)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Period	Begin 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
2	SAVINGS											
3	Gasoline Price Diff.		0	0	0	0	0	0	0	0	0	0
4	Vehicle Purchase Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
5	Infrastructure Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
6	Maintenance		0	0	0	0	0	0	0	0	0	0
7												
8												
9												
10	Total Savings	0	0	0	0	0	0	0	0	0	0	0
11												
12	COSTS											
13	Infrastructure											
14	Land											
15	Station setup	0	0	0	0	0	0	0	0	0	0	0
16	Compressor	0	0	0	0	0	0	0	0	0	0	0
17	Storage Vessels	0	0	0	0	0	0	0	0	0	0	0
18	Dispenser	0	0	0	0	0	0	0	0	0	0	0
19	Dryer	0	0	0	0	0	0	0	0	0	0	0
20	Subtotal	0	0	0	0	0	0	0	0	0	0	0
21												
22	Vehicle											
23	Conversion Kit	0	0	0	0	0	0	0	0	0	0	0
24	Tanks	0	0	0	0	0	0	0	0	0	0	0
25	Labor	0	0	0	0	0	0	0	0	0	0	0
26	OEM	0	0	0	0	0	0	0	0	0	0	0
27	Subtotal	0	0	0	0	0	0	0	0	0	0	0
28												
29	Operating											
30	Station Maint.		0	0	0	0	0	0	0	0	0	0
31	Cylinder Recert.		0	0	0	0	0	0	0	0	0	0
32	Power		0	0	0	0	0	0	0	0	0	0
33	Labor - fueling time loss		0	0	0	0	0	0	0	0	0	0
34	NG Fuel Tax		0	0	0	0	0	0	0	0	0	0
35	Additional Training											
36	Subtotal	0	0	0	0	0	0	0	0	0	0	0
37												
38	Total Costs	0	0	0	0	0	0	0	0	0	0	0
39												
40	Savings - Cost	0	0	0	0	0	0	0	0	0	0	0
41	NPV	0	0	0	0	0	0	0	0	0	0	0
42	NPV-cumulative	0	0	0	0	0	0	0	0	0	0	0
43	Discount Factor	1.000	1.100	1.210	1.331	1.464	1.611	1.772	1.949	2.144	2.358	2.594
44												
45	Benefit per vehicle per year	value										
47	VEHICLE DATA											
48	Automobiles:											
49	Number of Vehicles	0	0	0	0	0	0	0	0	0	0	0
51	Number New Conversions											
53	Number Kits Transferred											
55	Number Conversions Retired											
57	Number OEM											
59	Number OEM Retired											
61	Number Vehicle Needing Recert.											
63	Gasoline MPG	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
65	CNG MPG Adjust. Factor	0.95	0.95	0.95	0.95	0.95	1.15	1.15	1.15	1.15	1.15	1.15
66	CNG MPG	19.0	19.0	19.0	19.0	19.0	23.0	23.0	23.0	23.0	23.0	23.0
67	Dual-fuel MPG Adjust. Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
68	Dual-Fuel Gasoline MPG	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
70	Annual miles traveled per vehicle	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
71	Annual NG consump (scf)		0	0	0	0	0	0	0	0	0	0
72	Annual gasoline consump (gal)		0	0	0	0	0	0	0	0	0	0
73	Conversion Kit Cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000

Figure 3-3 (2 of 6)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Period	Begin 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
74	Conv. Kit Salvage Value	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
75	Conv. labor cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
76	Tank cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
77	Tank Salvage Value	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
78	OEM Cost Difference	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
79	OEM Salvage Value Difference	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
80	Fuel Capacity/tank (scf)	600	600	600	600	600	600	600	600	600	600	600
81	Number tanks/veh.	1	1	1	1	1	1	1	1	1	1	1
82	Tank Recert. Cost/tank	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50
83	% NG miles	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
84	Maint. Cost Difference/year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
85	Annual NG Fuel Tax per vehicle	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120
87	On-board gasoline capacity	16	16	16	16	16	16	16	16	16	16	16
89	FUEL PRICES											
90	Natural Gas Price/mcf	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085
91	Gasoline Price/gallon	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100
92	NG price/gallon gasoline equivalent	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379
93	Annual Fuel Price Adjustment	0.0%										
94	Total NG consump (scf)	0	0	0	0	0	0	0	0	0	0	0
95												
96	STATION DESIGN											
97	Useable Storage	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
98	Switch Time (min.)	3	3	3	3	3	3	3	3	3	3	3
99	NG Session Time (min.)	0	0	0	0	0	0	0	0	0	0	0
100	Flow Rate/hose (scfm)	500	500	500	500	500	500	500	500	500	500	500
101	Min. Comp. Size (scfm)	0	0	0	0	0	0	0	0	0	0	0
102	Max Storage (scf)	0	0	0	0	0	0	0	0	0	0	0
103	Design daily NG demand (scf)	0	0	0	0	0	0	0	0	0	0	0
104	Min. Comp. HP	3	3	3	3	3	3	3	3	3	3	3
105	Cycle Time (min)	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440
106	Number of Hoses	1	1	1	1	1	1	1	1	1	1	1
107	Autos per day	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
108	Auto NG per fill (scf)	537	537	537	537	537	537	537	537	537	537	537
109	Station Setup Cost Factor	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
110	Compressor Salvage Value											
111	Storage Vessel Salvage Val.											
112	Dispenser Salvage Value											
113	Dryer Salvage Value											
114												
115	Labor Time Loss Calculations:											
116	Gasoline fill rate (gal/min)	7	7	7	7	7	7	7	7	7	7	7
117	Gasoline/diesel switch time (min)	3	3	3	3	3	3	3	3	3	3	3
118	Labor Cost ($/hour)	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
119	Number of Gasoline hoses	2	2	2	2	2	2	2	2	2	2	2
120	Number of Autos/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
121	Dedicated Gasoline Session Time	0	0	0	0	0	0	0	0	0	0	0
122												
123	OTHER FACTORS											
124	Work days/year	350										
125	Fast-fill onboard storage	92.5%										
126	3000 psi comp factor	259.67										
127	100 psi comp factor	7.92										
128	Fuel in an "empty" tank (gal)	2										
129	NG to Gasoline Factor	123										
130	Station Maint cost/gas. gal. equiv.	$0.045										
131	Electric cost ($/kWh)	$0.063										
132	No. days off for tank recert.	5										
133	Discount Rate	10.0%										
134	Tax Rate	35.0%										
135	Beginning Period	1993										
136	Vehicle Tax Deduction Value	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1500
137	Infrastructure Tax Deduction Value	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	75000

Figure 3-3 (3 of 6)

	A	M	N	O	P	Q	S	T	U	V	W	X
1	Period	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2	SAVINGS											
3	Gasoline Price Diff.	0	0	0	0	0	0	0	0	0	0	0
4	Vehicle Purchase Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
5	Infrastructure Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
6	Maintenance	0	0	0	0	0	0	0	0	0	0	0
7												
8												
9												
10	Total Savings	0	0	0	0	0	0	0	0	0	0	0
11												
12	COSTS											
13	Infrastructure											
14	Land											
15	Station setup	0	0	0	0	0	3,948	0	0	0	0	0
16	Compressor	0	0	0	0	0	15,791	0	0	0	0	0
17	Storage Vessels	0	0	0	0	0	0	0	0	0	0	0
18	Dispenser	0	0	0	0	0	0	0	0	0	0	0
19	Dryer	0	0	0	0	0	0	0	0	0	0	0
20	Subtotal	0	0	0	0	0	19,739	0	0	0	0	0
21												
22	Vehicle											
23	Conversion Kit	0	0	0	0	0	0	0	0	0	0	0
24	Tanks	0	0	0	0	0	0	0	0	0	0	0
25	Labor	0	0	0	0	0	0	0	0	0	0	0
26	OEM	0	0	0	0	0	0	0	0	0	0	0
27	Subtotal	0	0	0	0	0	0	0	0	0	0	0
28												
29	Operating											
30	Station Maint.	0	0	0	0	0	0	0	0	0	0	0
31	Cylinder Recert.	0	0	0	0	0	0	0	0	0	0	0
32	Power	0	0	0	0	0	0	0	0	0	0	0
33	Labor - fueling time loss	0	0	0	0	0	0	0	0	0	0	0
34	NG Fuel Tax	0	0	0	0	0	0	0	0	0	0	0
35	Additional Training											
36	Subtotal	0	0	0	0	0	0	0	0	0	0	0
37												
38	Total Costs	0	0	0	0	0	19,739	0	0	0	0	0
39												
40	Savings - Cost	0	0	0	0	0	-19,739	0	0	0	0	0
41	NPV	0	0	0	0	0	-4,296	0	0	0	0	0
42	NPV-cumulative	0	0	0	0	0	-4,296	-4,296	-4,296	-4,296	-4,296	-4,296
43	Discount Factor	2.853	3.138	3.452	3.797	4.177	4.595	5.054	5.560	6.116	6.727	7.400
44												
45	Benefit per vehicle per year											
47	VEHICLE DATA											
48	Automobiles:											
49	Number of Vehicles	0	0	0	0	0	0	0	0	0	0	0
51	Number New Conversions											
53	Number Kits Transferred											
55	Number Conversions Retired											
57	Number OEM											
59	Number OEM Retired											
61	Number Vehicle Needing Recert.											
63	Gasoline MPG	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
65	CNG MPG Adjust. Factor	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
66	CNG MPG	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
67	Dual-fuel MPG Adjust. Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
68	Dual-Fuel Gasoline MPG	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
70	Annual miles traveled per vehicle	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
71	Annual NG consump (scf)	0	0	0	0	0	0	0	0	0	0	0
72	Annual gasoline consump (gal)	0	0	0	0	0	0	0	0	0	0	0
73	Conversion Kit Cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000

Figure 3-3 (4 of 6)

	A	M	N	O	P	Q	S	T	U	V	W	X
1	Period	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
74	Conv. Kit Salvage Value	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
75	Conv. labor cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
76	Tank cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
77	Tank Salvage Value	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
78	OEM Cost Difference	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
79	OEM Salvage Value Difference	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
80	Fuel Capacity/tank (scf)	600	600	600	600	600	600	600	600	600	600	600
81	Number tanks/veh.	1	1	1	1	1	1	1	1	1	1	1
82	Tank Recert. Cost/tank	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50
83	% NG miles	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
84	Maint. Cost Difference/year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
85	Annual NG Fuel Tax per vehicle	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120
87	On-board gasoline capacity	16	16	16	16	16	16	16	16	16	16	16
89	FUEL PRICES											
90	Natural Gas Price/mcf	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085
91	Gasoline Price/gallon	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100
92	NG price/gallon gasoline equivalent	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379
93	Annual Fuel Price Adjustment											
94	Total NG consump (scf)	0	0	0	0	0	0	0	0	0	0	0
95												
96	STATION DESIGN											
97	Useable Storage	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
98	Switch Time (min.)	3	3	3	3	3	3	3	3	3	3	3
99	NG Session Time (min.)	0	0	0	0	0	0	0	0	0	0	0
100	Flow Rate/hose (scfm)	500	500	500	500	500	500	500	500	500	500	500
101	Min. Comp. Size (scfm)	0	0	0	0	0	0	0	0	0	0	0
102	Max Storage (scf)	0	0	0	0	0	0	0	0	0	0	0
103	Design daily NG demand (scf)	0	0	0	0	0	0	0	0	0	0	0
104	Min. Comp. HP	3	3	3	3	3	3	3	3	3	3	3
105	Cycle Time (min)	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440
106	Number of Hoses	1	1	1	1	1	1	1	1	1	1	1
107	Autos per day	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
108	Auto NG per fill (scf)	537	537	537	537	537	537	537	537	537	537	537
109	Station Setup Cost Factor	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
110	Compressor Salvage Value						$0					
111	Storage Vessel Salvage Val.											
112	Dispenser Salvage Value											
113	Dryer Salvage Value											
114												
115	Labor Time Loss Calculations:											
116	Gasoline fill rate (gal/min)	7	7	7	7	7	7	7	7	7	7	7
117	Gasoline/diesel switch time (min)	3	3	3	3	3	3	3	3	3	3	3
118	Labor Cost ($/hour)	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
119	Number of Gasoline hoses	2	2	2	2	2	2	2	2	2	2	2
120	Number of Autos/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
121	Dedicated Gasoline Session Time	0	0	0	0	0	0	0	0	0	0	0
122												
123	OTHER FACTORS											
124	Work days/year											
125	Fast-fill onboard storage											
126	3000 psi comp factor											
127	100 psi comp factor											
128	Fuel in an "empty" tank (gal)											
129	NG to Gasoline Factor											
130	Station Maint cost/gas. gal. equiv.											
131	Electric cost ($/kWh)											
132	No. days off for tank recert.											
133	Discount Rate											
134	Tax Rate											
135	Beginning Period											
136	Vehicle Tax Deduction Value	1000	500	0	0	0	0	0	0	0	0	0
137	Infrastructure Tax Deduction Value	50000	25000	0	0	0	0	0	0	0	0	0

Figure 3-3 (5 of 6)

	A	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	Period	2014	2015	2016	2017	2018	2019	2020	2021	2022	End 2022	NPV
2	SAVINGS											
3	Gasoline Price Diff.	0	0	0	0	0	0	0	0	0	0	0
4	Vehicle Purchase Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
5	Infrastructure Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
6	Maintenance	0	0	0	0	0	0	0	0	0	0	0
7												
8												
9												
10	Total Savings	0	0	0	0	0	0	0	0	0	0	0
11												
12	COSTS											
13	Infrastructure											
14	Land											0
15	Station setup	0	0	0	0	0	0	0	0	0	0	-859
16	Compressor	0	0	0	0	0	0	0	0	0	-2,369	-3,301
17	Storage Vessels	0	0	0	0	0	0	0	0	0	0	0
18	Dispenser	0	0	0	0	0	0	0	0	0	0	0
19	Dryer	0	0	0	0	0	0	0	0	0	0	0
20	Subtotal	0	0	0	0	0	0	0	0	0	-2,369	-4,160
21												
22	Vehicle											
23	Conversion Kit	0	0	0	0	0	0	0	0	0	0	0
24	Tanks	0	0	0	0	0	0	0	0	0	0	0
25	Labor	0	0	0	0	0	0	0	0	0	0	0
26	OEM	0	0	0	0	0	0	0	0	0	0	0
27	Subtotal	0	0	0	0	0	0	0	0	0	0	0
28												
29	Operating											
30	Station Maint.	0	0	0	0	0	0	0	0	0	0	0
31	Cylinder Recert.	0	0	0	0	0	0	0	0	0	0	0
32	Power	0	0	0	0	0	0	0	0	0	0	0
33	Labor - fueling time loss	0	0	0	0	0	0	0	0	0	0	0
34	NG Fuel Tax	0	0	0	0	0	0	0	0	0	0	0
35	Additional Training											
36	Subtotal	0	0	0	0	0	0	0	0	0	0	0
37												
38	Total Costs	0	0	0	0	0	0	0	0	0	-2,369	-4,160
39												
40	Savings - Cost	0	0	0	0	0	0	0	0	0	2,369	-4,160
41	NPV	0	0	0	0	0	0	0	0	0	136	
42	NPV-cumulative	-4,296	-4,296	-4,296	-4,296	-4,296	-4,296	-4,296	-4,296	-4,296	-4,160	
43	Discount Factor	8.140	8.954	9.850	10.835	11.918	13.110	14.421	15.863	17.449	17.449	
44												
45	Benefit per vehicle per year											
47	VEHICLE DATA											
48	Automobiles:											
49	Number of Vehicles	0	0	0	0	0	0	0	0	0	0	
51	Number New Conversions											
53	Number Kits Transferred											
55	Number Conversions Retired											
57	Number OEM											
59	Number OEM Retired											
61	Number Vehicle Needing Recert.											
63	Gasoline MPG	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	
65	CNG MPG Adjust. Factor	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	
66	CNG MPG	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	
67	Dual-fuel MPG Adjust. Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	
68	Dual-Fuel Gasoline MPG	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	
70	Annual miles traveled per vehicle	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	
71	Annual NG consump (scf)	0	0	0	0	0	0	0	0	0	0	
72	Annual gasoline consump (gal)	0	0	0	0	0	0	0	0	0	0	
73	Conversion Kit Cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	

Figure 3-3 (6 of 6)

	A	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	Period	2014	2015	2016	2017	2018	2019	2020	2021	2022	End 2022	NPV
74	Conv. Kit Salvage Value	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	
75	Conv. labor cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	
76	Tank cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	
77	Tank Salvage Value	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
78	OEM Cost Difference	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	
79	OEM Salvage Value Difference	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	
80	Fuel Capacity/tank (scf)	600	600	600	600	600	600	600	600	600	600	
81	Number tanks/veh.	1	1	1	1	1	1	1	1	1	1	
82	Tank Recert. Cost/tank	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	
83	% NG miles	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
84	Maint. Cost Difference/year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
85	Annual NG Fuel Tax per vehicle	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120	
87	On-board gasoline capacity	16	16	16	16	16	16	16	16	16	16	
89	FUEL PRICES											
90	Natural Gas Price/mcf	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	$3.085	
91	Gasoline Price/gallon	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	
92	NG price/gallon gasoline equivalent	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	$0.379	
93	Annual Fuel Price Adjustment											
94	Total NG consump (scf)	0	0	0	0	0	0	0	0	0	0	
95												
96	STATION DESIGN											
97	Useable Storage	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	
98	Switch Time (min.)	3	3	3	3	3	3	3	3	3	3	
99	NG Session Time (min.)	0	0	0	0	0	0	0	0	0	0	
100	Flow Rate/hose (scfm)	500	500	500	500	500	500	500	500	500	500	
101	Min. Comp. Size (scfm)	0	0	0	0	0	0	0	0	0	0	
102	Max Storage (scf)	0	0	0	0	0	0	0	0	0	0	
103	Design daily NG demand (scf)	0	0	0	0	0	0	0	0	0	0	
104	Min. Comp. HP	3	3	3	3	3	3	3	3	3	3	
105	Cycle Time (min)	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	
106	Number of Hoses	1	1	1	1	1	1	1	1	1	1	
107	Autos per day	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
108	Auto NG per fill (scf)	537	537	537	537	537	537	537	537	537	537	
109	Station Setup Cost Factor	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	
110	Compressor Salvage Value										$2,369	
111	Storage Vessel Salvage Val.										$0	
112	Dispenser Salvage Value										$0	
113	Dryer Salvage Value										$0	
114												
115	Labor Time Loss Calculations:											
116	Gasoline fill rate (gal/min)	7	7	7	7	7	7	7	7	7	7	
117	Gasoline/diesel switch time (min)	3	3	3	3	3	3	3	3	3	3	
118	Labor Cost ($/hour)	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	
119	Number of Gasoline hoses	2	2	2	2	2	2	2	2	2	2	
120	Number of Autos/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
121	Dedicated Gasoline Session Time	0	0	0	0	0	0	0	0	0	0	
122												
123	OTHER FACTORS											
124	Work days/year											
125	Fast-fill onboard storage											
126	3000 psi comp factor											
127	100 psi comp factor											
128	Fuel in an "empty" tank (gal)											
129	NG to Gasoline Factor											
130	Station Maint cost/gas. gal. equiv.											
131	Electric cost ($/kWh)											
132	No. days off for tank recert.											
133	Discount Rate											
134	Tax Rate											
135	Beginning Period											
136	Vehicle Tax Deduction Value	0	0	0	0	0	0	0	0	0	0	
137	Infrastructure Tax Deduction Value	0	0	0	0	0	0	0	0	0	0	

Figure 3-4
Private Refueling Model Variables and Cell References

Variable Name	Spreadsheet Cell Reference	Variable Name	Spreadsheet Cell Reference
Annual.Fuel.Price.Adjustment	=$B$93	Discount.Rate	=$B$133
Auto.Annual.gasoline.consump.gal	=$B$72:$AH$72	Dispenser.costs	=$B$18:$AH$18
Auto.Annual.NG.consump.scf	=$B$71:$AH$71	Dispenser.Salvage.Value	=$B$112:$AH$112
Auto.Annual.NG.Fuel.Tax	=$B$85:AF$85	Dryer.Salvage.Value	=$B$113:$AH$113
Auto.CNG.mpg	=$B$66:$AH$66	Electric.cost.kwh	=$B$131
Auto.CNG.MPG.Adj.Factor	=$B$65:$AH$65	Fast.fill.onboard.storage	=$B$125
Auto.Conv.Kit.Cost	=$B$73:$AH$73	Flow.Rate.hose.scfm	=$B$100:$AH$100
Auto.Conv.Kit.Salvage.Value	=$B$74:$AH$74	Fuel.in.empty.tank.gal	=$B$128
Auto.Conv.lab.cost	=$B$75:$AH$75	Fuel.Price.Diff.	=$B$3
Auto.Dual.Fuel.Gasoline.MPG	=$B$68:$AH$68	Gasoline.diesel.switch.time	=$B$117:$AH$117
Auto.Dual.fuel.MPG.Adjust.Factor	=$B$67:$AH$67	Gasoline.fill.rate.gal.min	=$B$116:$AH$116
Auto.Fuel.Capacity.scf	=$B$80:$AH$80	Gasoline.Price.gallon	=$B$91:$AH$91
Auto.Gasoline.MPG	=$B$63:$AH$63	Infrastructure.Tax.Deduction.Value	=$A$137:$AH$137
Auto.Maint.Cost.Diff	=$B$84:$AH$84	Labor.Cost.hour	=$B$118:$AH$118
Auto.miles	=$B$70:$AH$70	Labor.costs	=$B$25:$AH$25
Auto.NG.per.fill.scf	=$B$108:$AH$108	Land.costs	=$B$14:$AH$14
Auto.Num.CNG.Converted	=$B$51:$AH$51	Max.Storage.scf	=$B$102:$AH$102
Auto.Num.CNG.Retired	=$B$55:$AH$55	Min.Comp.HP	=$B$104:$AH$104
Auto.Num.CNG.Trans	=$B$53:$AH$53	Min.Comp.Size.scfm	=$B$101:$AH$101
Auto.Num.Need.Recert	=$B$61:$AH$61	Natural.Gas.Price.mcf	=$B$90:$AH$90
Auto.Num.OEM	=$B$57:$AH$57	NG.Gasoline.Factor	=$B$129
Auto.Num.OEM.Retired	=$B$59:$AH$59	NG.price.gallon.gasoline.equivalent	=$B$92:$AH$92
Auto.Num.Vehicles	=$B$49:$AH$49	NG.Session.Time.min	=$B$99:$AH$99
Auto.OEM.Cost.Diff	=$B$78:$AH$78	Number.Autos.day	=$B$120:$AH$120
Auto.OEM.Salvage.Value	=$B$79:$AH$79	Number.Gasoline.hoses	=$B$119:$AH$119
Auto.On.board.gasoline.capacity	=$A$87:$AH$87	Number.of.Hoses	=$B$106:$AH$106
Auto.Prcnt.NG.miles	=$B$83:$AH$83	OEM.costs	=$B$26:$AH$26
Auto.Tank.cost	=$B$76:$AH$76	Period	=$A$1:$AH$1
Auto.Tank.Recert.Cost	=$B$82:$AH$82	Station.Maint.cost.gale	=$B$130
Auto.Tank.Salvage.Value	=$B$77:$AH$77	Station.Setup.Cost.Factor	=$B$109:$AH$109
Auto.tanks.per.veh.	=$B$81:$AH$81	Station.setup.costs	=$B$15:$AH$15
Autos.per.day	=$B$107:$AH$107	Storage.Vessel.Salv.Val	=$B$111:$AH$111
Beginning.Period	=$B$135	Storage.Vessels.costs	=$B$17:$AH$17
Compressor.costs	=$B$16:$AH$16	Switch.Time.min	=$B$98:$AH$98
Compressor.Salvage.Value	=$B$110:$AH$110	Tank.fill.factor.100psi	=$B$127
Conversion.Kit.costs	=$B$23:$AH$23	Tank.fill.factor.3000psi	=$B$126
Cost.per.veh.per.year	=$B$45	Tanks.costs	=$B$24:$AH$24
Cumulative.NPV	=$AI$40	Tax_Rate	=$B$134
Cycle.Time	=$B$105:$AH$105	Total.NG.consump.scf	=$B$94:$AH$94
Days.off.tank.recert	=$B$132	Useable.Storage	=$B$97:$AH$97
Ded.Gasoline.Session.Time	=$B$121:$AH$121	Vehicle.Tax.Deduction.Value	=$A$136:$AH$136
Design.Daily.NG.demand.scf	=$B$103:$AH$103	Work.days.year	=$B$124

(5) Fuel.in.empty.tank.gal - it is assumed that 2 gallons (7.6 L) of gasoline remain in the tank when the vehicle is filled.

(6) NG.Gasoline.Factor - the amount of natural gas (scf) with an equivalent amount of energy as a gallon of gasoline. This is calculated by dividing the net (or lower) heating value of a gallon of gasoline by the net (or lower) heating value of a standard cubic foot of natural gas. This factor is taken to be 114,132 / 930 = 122.7 scf/gallon (1.06 m^3/L) gasoline (EPA, 1990; Osgoode).

(7) Station.Maint.cost.gallon.gale - station maintenance is often reported as a function of the number of gasoline gallon equivalents compressed. Values for this factor range from 2 to 10 cents per gallon equivalent (0.53¢ to 2.64¢ per liter) (AGA, 1989; DeLuchi et al, 1988; IANGV, 1990; EPA, 1988; EPA, 1990). Here we assume a value of 4.5 cents (1.19¢/L), based on DeLuchi's assumptions (DeLuchi et al, 1988). Note that compressor maintenance is also very sensitive to the number of times the compressor is toggled on and off, which this factor does not consider (Slack). The way the compressor size is estimated in this model does minimize toggling.

(8) Electricity.cost.kwh - cost of electricity to the fleet. Assumed to be 6.3 cents per kilowatt-hour (kWh).

(9) Days.off.tank.recert - for on-board tank recertification, it is assumed that it will take 20 days to take the tanks off the vehicle, deliver them to a testing facility, have them tested, returned, and reinstalled on the vehicle.

(10) Discount.Rate - a discount rate of 10 percent is used in the base case.

(11) Beginning Period - Sets the beginning period of the life-cycle analysis.

Vehicle Data. This section contains input data for the vehicle.

(1) Auto.CNG.MPG.Adj.Factor - it is assumed that converted CNG vehicles will achieve fuel efficiencies 95 percent of the original gasoline vehicle, while operating on natural gas. This assumes that the conversion does not optimize the engine for natural gas usage. The major reason for the decrease is the added weight of the CNG cylinders. Note that this factor changes to 115 percent after introduction of OEM. It is assumed that OEM vehicles are available in year 5 for the base case. They are assumed to be optimized and dedicated and will therefore achieve greater fuel efficiencies than gasoline vehicles (DeLuchi et al, 1988; EPA, 1990).

(2) Auto.Dual.fuel.MPG.Adjust.Factor - it is assumed that converted CNG vehicles will achieve fuel efficiencies 95 percent of the original gasoline vehicle, while running on gasoline. This assumes that the conversion does not optimize the engine for natural gas usage. The major reason for the decrease is the added weight of the CNG cylinders.

(3) Auto.Conv.Kit.Cost - is the cost of the under-hood equipment (i.e., mixer, regulator, piping, etc.). This cost is assumed to be $1,000.

(4) Auto.Conv.lab.cost - is the cost of labor to perform the conversion. This cost is assumed to be $1,000.

(5) Auto.Tank.cost - is the cost of one composite tank, estimated at $1,000.

(6) Auto.Conv.Kit.Salvage.Value - is the price difference in selling a used converted CNG vehicle versus the same vehicle if it were not converted. It is assumed this value is $200. As defined, this value includes both tank, kit, and labor salvage value.

(7) Auto.Tank.Salvage.Value - this value is currently not used (it is set to $0). The salvage value of tanks is included in VehType.Conv.Kit.Salvage.Value.

(8) Auto.OEM.Cost.Diff - this is the cost difference between an original equipment manufacturer (OEM) dedicated optimized CNG vehicle and a comparable gasoline or diesel vehicle. It is assumed that this difference is $2,500 for full-scale OEM production.

(9) Auto.OEM.Salvage.Value - is the price difference in selling a used OEM CNG vehicle versus a comparable gasoline vehicle. It is assumed this value is $200.

(10) Auto.Fuel.Capacity.scf - the amount of natural gas that can be stored in the tank at 3,000 psig (2.1 kg/mm^2) at standard temperature. This is assumed to be 600 scf (19.7 m^3) (TxDOT, 1990).

(11) Auto.tanks.per.veh - autos - 1 tank.

(12) Auto.Tank.Recert.Cost - cost to recertify one composite tank is assumed to be $40 (if steel, assumption would be $20), plus the cost of one hour of labor to remove the tank, transport it to and from the testing facility, and replace it on the vehicle (Funk).

(13) Auto.Prcnt.NG.miles - percentage of miles driven per vehicle on natural gas. Assumed to be 100 percent for dual-fuel vehicles. Must be 100 percent for dedicated OEM vehicles.

(14) Auto.Maint.Cost.Diff - difference in costs for one vehicle's maintenance in one year.

(15) Auto.On.board.gasoline.capacity - assumed to be 16 gallons (60.6 L).

Fuel Prices. The following values are used.

(1) Natural Gas Price/mcf - price per thousand standard cubic feet (mcf). $3.085 ($0.09/m^3) is assumed, which includes $0.4854 ($0.01/m^3) federal fuel tax.

(2) Gasoline Price/gallon - assumed to be $1.10 ($0.29/L), and includes federal and state tax.

(3) Annual Fuel Price Adjustment - allows all fuel prices to be increased at a certain percentage per year. It is assumed that fuel prices remain constant over time (except for inflation), so this adjustment is set to 0.0 percent.

Station Design. The following variables and values are used to design a fast-fill station.

(1) Usable.Storage - the percentage of natural gas that can be drawn from a fully charged cascade before it is considered depleted. This value is assumed to be 40 percent.

(2) Switch.Time.min - time to pull vehicle up to station, get out of vehicle, connect fuel probe, disconnect fill probe, get back into vehicle, and drive away. Includes all time except time that natural gas is actually being transferred to the vehicle. This time is assumed to be 3 minutes.

(3) Flow.Rate.hose.scfm - the average flow rate per hose achievable by the station while continuously fueling vehicles until the storage is depleted. It is assumed to be 300 standard cubic feet per minute (scfm) (9.84 m^3/minute), but values up to 1,000 scfm (32.8 m^3/minute) have been reported (Pearson; Blazek). This value does not change the cost of the station significantly [station cost will increase slightly for 1,000 scfm (32.8 m^3/minute)], but labor fueling time losses will decrease significantly as this value increases.

(4) Cycle.Time - a cycle is the time for one continuous fueling session and the time to recharge storage before the next session. It is assumed that one continuous fueling session occurs daily and that the rest of the day's time is used to recharge storage. Thus, the cycle time is the number of minutes per day (1,440).

(5) Number.of.Hoses - 2 CNG hoses are assumed. This variable is directly related to the dispenser cost, so they must be changed in tandem.

(6) Station.Setup.Cost.Factor - the cost of miscellaneous items such as piping, labor, and construction overhead is approximated by assuming that it is equal to 25 percent of the total cost of the compressor, storage vessels, and dispenser (USDOE, 1990).

(7) Compressor.Salvage.Value - is assumed to be 15 percent of the original cost (after 15 years).

(8) Storage.Vessel.Salv.Val - is assumed to be 50 percent of the original cost (after 30 years).

(9) Dispenser.Salvage.Value - is assumed to be 10 percent of the original cost (after 30 years).

(10) Dryer.Salvage.Value - is assumed to be 10 percent of the original cost (after 30 years).

Labor Time Loss Calculation. The following variables are used in the labor time loss calculation.

(1) Gasoline.fill.rate.gal.min - assumed to be 7 gallons/minute (26.5 L/minute) (without topping off tank).

(2) Gasoline.diesel.switch.time - same definition as for natural gas switch time. This time is assumed to be 3 minutes.

(3) Labor.Cost.hour - cost per person-hour for fueling vehicles and recertifying tanks (includes salary, benefits, etc.). Assumed to be $10.00.

(4) Number.Gasoline.hoses - assumed to be 2.

Costs. Dispenser costs are assumed to be $25,000 for two metered hoses or $20,000 for 1 metered hose. Dryer costs are approximately $25,000 for a regenerative unit, similar to those required for public stations by new standards. This figure can be considered a maximum cost.

Some cost savings are obtainable by using non-regenerative units, where chemicals must be changed periodically (Petsinger).

Input Data (variable)

This section of input data is data that will be different for each fleet analyzed. This is where fleet-specific variables are input.

Vehicle Data. This section contains input data for each vehicle type. Note that the yearly data entered for the number of new conversions, conversions retired, kits transferred, OEMs purchased, and OEMs retired are based on the operating life of the taxi. The criteria used for determining the operating life of a taxi is based strictly on mileage. A taxi's life is considered over when it exceeds 200,000 miles (322,000 km).

(1) Auto.Num.CNG.Converted - this is the number of vehicles converted to dual-fuel CNG operation in a certain year.

(2) Auto.Num.CNG.Trans - when converted vehicles reach the end of their operating life at the beginning of a specific year, their kits and tanks are assumed to be transferred to the new replacement vehicles, unless OEM vehicles are available. In that case, the kit is salvaged.

(3) Auto.Num.CNG.Retired - number of converted vehicles reaching the end of their operating life at the beginning of this year.

(4) Auto.Num.OEM - number of OEM CNG vehicles purchased at the beginning of this year.

(5) Auto.Num.OEM.Retired - number of OEM CNG vehicles reaching the end of their operating life at the beginning of this year.

(6) Auto.Num.Need.Recert - number of converted CNG vehicles needing tank recertification in this year. Composite tanks must be recertified every 3 years and steel tanks every 5 years. [There are new tanks available that last 15 years (Petsinger).]

(7) Auto.Gasoline.MPG - average fuel efficiency per vehicle. Assumed to be 20 miles per gallon (8.5km/L) for taxis.

(8) Auto.miles - annual miles traveled for this vehicle type at this location. Assumed to be 100,000 miles (161,000 km) for taxis.

Other Factors. This section is used as inputs for the tax deduction calculations.

(1) Tax.Rate - An effective tax rate of 35 percent is used.

(2) Vehicle Tax Deduction Value. This value is based on the Energy Policy Act. The deduction limit is $2,000 through the year 2001 and is phased out through 2004.

(3) Infrastructure Tax Deduction Value. This value is based on the Energy Policy Act. It amounts to a maximum of \$100,000 and is phased out beginning in the year 2002.

Calculations

This section gives the equations used in all calculations, with an explanation of the inherent assumptions, where required. Figure 3.4 lists all the variable names and their spreadsheet cell references.

Vehicle Data. The following variables are used in the Vehicle Data section of the model.

```
Auto.Num.Vehicles =
   (Auto.Num.CNG.Converted + Auto.Num.OEM + Auto.Num.CNG.Trans)-
   (Auto.Num.CNG.Retired + Auto.Num.OEM.Retired)

Auto.CNG.mpg =
   Auto.Gasoline.MPG * Auto.CNG.MPG.Adj.Factor

Auto.Dual.Fuel.Gasoline.MPG =
   Auto.Gasoline.MPG * Auto.Dual.fuel.MPG.Adjust.Factor

Auto.Annual.NG.consump.scf =
   (((Auto.Num.Vehicles - Auto.Num.Need.Recert) * Auto.miles * Auto.Prcnt.NG.miles) /
   (Auto.CNG.mpg) * NG.Gasoline.Factor) +
   ((Auto.Num.Need.Recert * ((Work.days.year - Days.off.tank.recert) / Work.days.year) *
   Auto.miles * Auto.Prcnt.NG.miles) / (Auto.CNG.mpg) * NG.Gasoline.Factor)

Auto.Annual.gasoline.consumption.gal =
   ((Auto.Num.Vehicles - Auto.Num.Need.Recert) *
   Auto.miles * (1 - Auto.Prcnt.NG.miles) / Auto.Dual.Fuel.Gasoline.MPG) +
   ((Auto.Num.Need.Recert *
   ((Work.days.year - Days.off.tank.recert) / Work.days.year) *
   Auto.miles * (1 - Auto.Prcnt.NG.miles) / Auto.Dual.Fuel.Gasoline.MPG)) +
   ((Auto.Num.Need.Recert * (Days.off.tank.recert / Work.days.year) * Auto.miles) /
   Auto.Dual.Fuel.Gasoline.MPG)
```

An annual fuel tax is required by Texas law. The amount charged is based on weight and annual mileage of the vehicle. Vehicle weights for taxis are assumed to be less than 4,000 lbs (1816 kg).

```
Auto.Annual.NG.Fuel.Tax =
   IF(0<Auto.miles<5000,$30)
   IF(5001<Auto.miles<10000,$60)
   IF(10001<Auto.miles<15000,$90)
   ELSE($120)
```

Fuel Prices. The following formulas are used in the calculation of fuel prices.

NG.price.gallon.gasoline.equivalent =
(Natural.Gas.Price.mcf/1,000) * NG.Gasoline.Factor

Total.NG.consumption.scf =
Auto.Annual.NG.consump.scf

Station Design. The following formulas are used to calculate the optimal station design.

NG.Session.Time.min =
((Autos.per.day / Number.of.Hoses) * (Switch.Time.min +
(Auto.NG.per.fill.scf / Flow.Rate.hose.scfm)))

Design.Daily.NG.demand.scf =
(Auto.Num.Vehicles * Auto.miles * Auto.Prcnt.NG.miles / Auto.CNG.mpg *
NG.Gasoline.Factor) / Work.days.year

The inherent assumption in the following equation is that the cheapest station design is to minimize compressor size by allowing it to run 24 hours/day and maximize storage. This may not always be the case, but even if not, it yields costs that are in the ballpark for the purpose of this analysis, given the uncertainty in all costs and savings.

Min.Comp.Size.scfm =
Design.Daily.NG.demand.scf / Cycle.Time

An inherent assumption in the following equation is that the station is designed to fill all the required vehicles continuously in one session per cycle. Less storage is required if more sessions are allowed per cycle (such as morning and evening sessions or vehicles fueling uniformly throughout the day), which can result in significant costs savings (Taylor et al, 1992).

Max.Storage.scf =
Design.Daily.NG.demand.scf / (Useable.Storage * (1 + (NG.Session.Time.min /
(Cycle.Time - NG.Session.Time.min))))

The following equation was derived by a curve-fit to actual size/HP data.

Min.Comp.HP =
2.6588 + (0.54898 * Min.Comp.Size.scfm)

The assumption inherent in the following two equations is that vehicles fuel when they are almost empty.

Autos.per.day =
(Auto.Num.Vehicles * Auto.miles * Auto.Prcnt.NG.miles / Auto.CNG.mpg * NG.Gasoline.Factor) / ((Auto.NG.per.fill.scf) * Work.days.year)

Auto.NG.per.fill.scf =
(Auto.Fuel.Capacity.scf * Auto.tanks.per.veh. * Fast.fill.onboard.storage) - (((Auto.Fuel.Capacity.scf * Auto.tanks.per.veh.) / Tank.fill.factor.3,000psi) * Tank.fill.factor.100psi)

Labor Time Loss Calculations. The assumption inherent in the following two equations is that vehicles fuel when they are almost empty. These are the number of dedicated gasoline vehicles requiring fueling daily to offset the natural gas usage of their replacement CNG vehicles. These values can then be used to calculate dedicated gasoline fueling session times which are directly comparable with the natural gas fueling session time, in order to compute labor losses due to fueling. Thus, the computation of labor losses assumes that the fueling of converted dual-fuel vehicles with gasoline would take the same amount of time as fueling the original gasoline vehicle, for the miles (kilometers) a dual-fuel vehicle utilizes gasoline. In actuality this is not the case, since gasoline fuel efficiency drops when the vehicle is converted. However, this error is small and is therefore ignored in order to make computations simpler. In fact, there is no error for gasoline vehicles if 100 percent of the distance is driven on CNG, as is the case for taxis in this analysis.

Number.Autos.day =
((Auto.Num.Vehicles * (Auto.miles * Auto.Prcnt.NG.miles / Auto.Gasoline.MPG)) / Work.days.year) / (Auto.On.board.gasoline.capacity - Fuel.in.empty.tank.gal)

The following equation calculates the continuous fueling session time necessary if dedicated gasoline vehicles are retained.

Ded.Gasoline.Session.Time =
((Number.Autos.day / Number.Gasoline.hoses) * (Gasoline.diesel.switch.time + (Auto.On.board.gasoline.capacity / Gasoline.fill.rate.gal.min)))

Savings.

Gasoline Price Differential =
((((Auto.miles * Auto.Num.Vehicles) / Auto.Gasoline.MPG) * Gasoline.Price.gallon) - (Auto.Annual.NG.consump.scf * (Natural.Gas.Price.mcf/1,000)) - (Auto.Annual.gasoline.consump.gal * Gasoline.Price.gallon))

Vehicle Purchase Tax Deduction
If Auto.Conv.Kit.Cost + Auto.Conv.lab.cost + (Auto.Tank.cost * Auto.tanks.per.veh.) > Vehicle.Tax.Deduction.Value

Then Vehicle Purchase Tax Deduction = Vehicle.Tax.Deduction.Value * Tax_Rate * (Auto.Num.CNG.Converted + Auto.Num.OEM)

Otherwise Vehicle Purchase Tax Deduction = Auto.Conv.Kit.Cost + Auto.Conv.lab.cost + (Auto.Tank.cost * Auto.tanks.per.veh.) * Tax_Rate * (Auto.Num.CNG.Converted + Auto.Num.OEM)

Infrastructure Tax Deduction
If Total Infrastructure Costs are > Infrastructure.Tax.Deduction.Value

Then Infrastructure Tax Deduction = Infrastructure.Tax.Deduction.Value * Tax_Rate

Otherwise Infrastructure Tax Deduction = Total Infrastructure Costs * Tax_Rate

Maintenance savings =
(Auto.Num.Vehicles * Auto.Maint.Cost.Diff)

Costs.

(1) Infrastructure.

Land costs are assumed to be sunk costs.

Station Setup =
Station.Setup.Cost.Factor * (Compressor.costs + Storage.Vessels.costs + Dispenser.costs)

The following two equations were derived by curve-fitting to actual size/cost data. For the compressor, 5 psig (0.0035 kg/mm^2) inlet pressure was assumed.

Compressor =
(15,791 + (482.38 * Min.Comp.Size.scfm) + (0.16734 * (Min.Comp.Size.scfm ^ 2)) - (0.001037 * (Min.Comp.Size.scfm ^ 3)))

Storage Vessels =
(-487.55 + (1.0889 * Max.Storage.scf))

(2) Vehicle

Conversion Kit =
(Auto.Num.CNG.Converted * Auto.Conv.Kit.Cost) - (Auto.Num.CNG.Retired * Auto.Conv.Kit.Salvage.Value)

Tanks =
(Auto.Num.CNG.Converted * Auto.Tank.cost * Auto.tanks.per.veh.) -
(Auto.Num.CNG.Retired * Auto.Tank.Salvage.Value * Auto.tanks.per.veh.)

Labor =
((Auto.Num.CNG.Converted + Auto.Num.CNG.Trans) * Auto.Conv.lab.cost)

OEM =
(Auto.Num.OEM * Auto.OEM.Cost.Diff) - (Auto.Num.OEM.Retired *
Auto.OEM.Salvage.Value)

(3) Operating

Station Maintenance =
(Total.NG.consump.scf / NG.Gasoline.Factor) * Station.Maint.cost.gale

Cylinder Recertification =
Auto.Num.Need.Recert * Auto.tanks.per.veh. * Auto.Tank.Recert.Cost

This power cost estimate is a maximum cost; the actual cost will be somewhat less. This estimate assumes that the compressor motor draws full current at all times. This is the case only if the back-pressure on the compressor is at its maximum (i.e., when compressing into a full storage vessel).

Power =
Min.Comp.HP *
Auto.Annual.NG.consump.scf / Min.Comp.Size.scfm * 0.745712 / 60 * Electric.cost.kwh

Labor Fueling Time Loss =
((Number.of.Hoses * NG.Session.Time.min - Number.Gasoline.hoses *
Ded.Gasoline.Session.Time) / 60) * Work.days.year * Labor.Cost.hour

NG Fuel Tax =
Auto.Num.Vehicles * Auto.Annual.NG.Fuel.Tax

Additional training can include costs to train mechanics to work on CNG vehicles, costs to train drivers to operate CNG vehicles, costs to train maintenance workers to perform fueling station maintenance, etc. There is no cost added for this item.

Cost per Vehicle per Year. This cost allows one to compare conversion of different size fleets or to compute things such as gasoline taxes required to make conversion cost-effective. It is calculated by computing an annuity equivalent to the Cumulative NPV and then dividing this annuity by the number of vehicles in the fleet. This value is not valid if the number of vehicles does not remain constant over the entire analysis time period.

Embedded Model Assumptions

This section presents the embedded model assumptions that have not been discussed previously.

It is assumed that ASME vessels are used for fueling station storage. Therefore, no recertification is required for these vessels.

No savings are accrued for power cost savings or maintenance savings due to reduced usage of gasoline/diesel fuel dispensers. Nor are any savings given for possible elimination of gasoline/diesel fueling stations.

On-board composite CNG cylinders requiring recertification every 3 years are assumed, although available are composites that do not require recertification for 15 years and steel cylinders that require recertification only every 5 years (Taylor et al, 1992; Funk).

NATURAL GAS MODEL WITH PUBLIC REFUELING

This model is the same as the private refueling model, except that all infrastructure costs, operating costs related to infrastructure, and the infrastructure tax benefit are eliminated. The spreadsheet model is shown in Figure 3-5, with the variable names and cell references listed in Figure 3-6.

Figure 3-5 (1 of 6)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Period	Begin 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
2	SAVINGS											
3	Gasoline Price Diff.		0	0	0	0	0	0	0	0	0	0
4	Vehicle Purchase Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
5	Infrastructure Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
6	Maintenance		0	0	0	0	0	0	0	0	0	0
7												
8												
9												
10	Total Savings	0	0	0	0	0	0	0	0	0	0	0
11												
12	COSTS											
22	Vehicle											
23	Conversion Kit	0	0	0	0	0	0	0	0	0	0	0
24	Tanks	0	0	0	0	0	0	0	0	0	0	0
25	Labor	0	0	0	0	0	0	0	0	0	0	0
26	OEM	0	0	0	0	0	0	0	0	0	0	0
27	Subtotal	0	0	0	0	0	0	0	0	0	0	0
28												
29	Operating											
31	Cylinder Recert.		0	0	0	0	0	0	0	0	0	0
33	Labor - fueling time loss		0	0	0	0	0	0	0	0	0	0
34	NG Fuel Tax		0	0	0	0	0	0	0	0	0	0
35	Additional Training											
36	Subtotal	0	0	0	0	0	0	0	0	0	0	0
37												
38	Total Costs	0	0	0	0	0	0	0	0	0	0	0
39												
40	Savings - Cost	0	0	0	0	0	0	0	0	0	0	0
41	NPV	0	0	0	0	0	0	0	0	0	0	0
42	NPV-cumulative	0	0	0	0	0	0	0	0	0	0	0
43	Discount Factor	1.000	1.100	1.210	1.331	1.464	1.611	1.772	1.949	2.144	2.358	2.594
44												
45	Benefit per vehicle per year	value										
47	VEHICLE DATA											
48	Automobiles:											
49	Number of Vehicles	0	0	0	0	0	0	0	0	0	0	0
51	Number New Conversions											
53	Number Kits Transferred											
55	Number Conversions Retired											
57	Number OEM											
59	Number OEM Retired											
61	Number Vehicle Needing Recert.											
63	Gasoline MPG	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
65	CNG MPG Adjust. Factor	0.95	0.95	0.95	0.95	0.95	1.15	1.15	1.15	1.15	1.15	1.15
66	CNG MPG	19.0	19.0	19.0	19.0	19.0	23.0	23.0	23.0	23.0	23.0	23.0
67	Dual-fuel MPG Adjust. Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
68	Dual-Fuel Gasoline MPG	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
70	Annual miles traveled per vehicle	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
71	Annual NG consump (scf)		0	0	0	0	0	0	0	0	0	0
72	Annual gasoline consump (gal)		0	0	0	0	0	0	0	0	0	0
73	Conversion Kit Cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
74	Conv. Kit Salvage Value	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
75	Conv. labor cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
76	Tank cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
77	Tank Salvage Value	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
78	OEM Cost Difference	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
79	OEM Salvage Value Difference	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200

Figure 3-5 (2 of 6)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Period	Begin 1993	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
80	Fuel Capacity/tank (scf)	600	600	600	600	600	600	600	600	600	600	600
81	Number tanks/veh.	1	1	1	1	1	1	1	1	1	1	1
82	Tank Recert. Cost/tank	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50
83	% NG miles	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
84	Maint. Cost Difference/year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
85	Annual NG Fuel Tax per vehicle	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120
87	On-board gasoline capacity	16	16	16	16	16	16	16	16	16	16	16
89	FUEL PRICES											
90	Natural Gas Price/mcf	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785
91	Gasoline Price/gallon	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100
92	NG price/gallon gasoline equivalent	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710
93	Annual Fuel Price Adjustment	0.0%										
94	Total NG consump (scf)	0	0	0	0	0	0	0	0	0	0	0
95												
96	STATION DESIGN											
97	Useable Storage	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
98	Switch Time (min.)	3	3	3	3	3	3	3	3	3	3	3
99	NG Session Time (min.)	0	0	0	0	0	0	0	0	0	0	0
100	Flow Rate/hose (scfm)	500	500	500	500	500	500	500	500	500	500	500
101	Min. Comp. Size (scfm)	0	0	0	0	0	0	0	0	0	0	0
102	Max Storage (scf)	0	0	0	0	0	0	0	0	0	0	0
103	Design daily NG demand (scf)	0	0	0	0	0	0	0	0	0	0	0
104	Min. Comp. HP	3	3	3	3	3	3	3	3	3	3	3
105	Cycle Time (min)	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440
106	Number of Hoses	1	1	1	1	1	1	1	1	1	1	1
107	Autos per day	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
108	Auto NG per fill (scf)	537	537	537	537	537	537	537	537	537	537	537
109	Station Setup Cost Factor	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
110	Compressor Salvage Value											
111	Storage Vessel Salvage Val.											
112	Dispenser Salvage Value											
113	Dryer Salvage Value											
114												
115	Labor Time Loss Calculations:											
116	Gasoline fill rate (gal/min)	7	7	7	7	7	7	7	7	7	7	7
117	Gasoline/diesel switch time (min)	3	3	3	3	3	3	3	3	3	3	3
118	Labor Cost ($/hour)	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
119	Number of Gasoline hoses	2	2	2	2	2	2	2	2	2	2	2
120	Number of Autos/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
121	Dedicated Gasoline Session Time	0	0	0	0	0	0	0	0	0	0	0
122												
123	OTHER FACTORS											
124	Work days/year	350										
125	Fast-fill onboard storage	92.5%										
126	3000 psi comp factor	259.67										
127	100 psi comp factor	7.92										
128	Fuel in an "empty" tank (gal)	2										
129	NG to Gasoline Factor	123										
130	Station Maint cost/gas. gal. equiv.	$0.045										
131	Electric cost ($/kWh)	$0.063										
132	No. days off for tank recert.	5										
133	Discount Rate	10.0%										
134	Tax Rate	35.0%										
135	Beginning Period	1993										
136	Vehicle Tax Deduction Value	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1500
137	Infrastructure Tax Deduction Value	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	75000

Figure 3-5 (3 of 6)

	A	M	N	O	P	Q	S	T	U	V	W	X
1	Period	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2	SAVINGS											
3	Gasoline Price Diff.	0	0	0	0	0	0	0	0	0	0	0
4	Vehicle Purchase Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
5	Infrastructure Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
6	Maintenance	0	0	0	0	0	0	0	0	0	0	0
7												
8												
9												
10	Total Savings	0	0	0	0	0	0	0	0	0	0	0
11												
12	COSTS											
22	Vehicle											
23	Conversion Kit	0	0	0	0	0	0	0	0	0	0	0
24	Tanks	0	0	0	0	0	0	0	0	0	0	0
25	Labor	0	0	0	0	0	0	0	0	0	0	0
26	OEM	0	0	0	0	0	0	0	0	0	0	0
27	Subtotal	0	0	0	0	0	0	0	0	0	0	0
28												
29	Operating											
31	Cylinder Recert.	0	0	0	0	0	0	0	0	0	0	0
33	Labor - fueling time loss	0	0	0	0	0	0	0	0	0	0	0
34	NG Fuel Tax	0	0	0	0	0	0	0	0	0	0	0
35	Additional Training											
36	Subtotal	0	0	0	0	0	0	0	0	0	0	0
37												
38	Total Costs	0	0	0	0	0	0	0	0	0	0	0
39												
40	Savings - Cost	0	0	0	0	0	0	0	0	0	0	0
41	NPV	0	0	0	0	0	0	0	0	0	0	0
42	NPV-cumulative	0	0	0	0	0	0	0	0	0	0	0
43	Discount Factor	2.853	3.138	3.452	3.797	4.177	4.595	5.054	5.560	6.116	6.727	7.400
44												
45	Benefit per vehicle per year											
47	VEHICLE DATA											
48	Automobiles:											
49	Number of Vehicles	0	0	0	0	0	0	0	0	0	0	0
51	Number New Conversions											
53	Number Kits Transferred											
55	Number Conversions Retired											
57	Number OEM											
59	Number OEM Retired											
61	Number Vehicle Needing Recert.											
63	Gasoline MPG	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
65	CNG MPG Adjust. Factor	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
66	CNG MPG	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
67	Dual-fuel MPG Adjust. Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
68	Dual-Fuel Gasoline MPG	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
70	Annual miles traveled per vehicle	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
71	Annual NG consump (scf)	0	0	0	0	0	0	0	0	0	0	0
72	Annual gasoline consump (gal)	0	0	0	0	0	0	0	0	0	0	0
73	Conversion Kit Cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
74	Conv. Kit Salvage Value	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
75	Conv. labor cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
76	Tank cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
77	Tank Salvage Value	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
78	OEM Cost Difference	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
79	OEM Salvage Value Difference	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200

Figure 3-5 (4 of 6)

	A	M	N	O	P	Q	S	T	U	V	W	X
1	Period	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
80	Fuel Capacity/tank (scf)	600	600	600	600	600	600	600	600	600	600	600
81	Number tanks/veh.	1	1	1	1	1	1	1	1	1	1	1
82	Tank Recert. Cost/tank	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50
83	% NG miles	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
84	Maint. Cost Difference/year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
85	Annual NG Fuel Tax per vehicle	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120
87	On-board gasoline capacity	16	16	16	16	16	16	16	16	16	16	16
89	FUEL PRICES											
90	Natural Gas Price/mcf	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785
91	Gasoline Price/gallon	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100
92	NG price/gallon gasoline equivalent	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710
93	Annual Fuel Price Adjustment											
94	Total NG consump (scf)	0	0	0	0	0	0	0	0	0	0	0
95												
96	STATION DESIGN											
97	Useable Storage	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
98	Switch Time (min.)	3	3	3	3	3	3	3	3	3	3	3
99	NG Session Time (min.)	0	0	0	0	0	0	0	0	0	0	0
100	Flow Rate/hose (scfm)	500	500	500	500	500	500	500	500	500	500	500
101	Min. Comp. Size (scfm)	0	0	0	0	0	0	0	0	0	0	0
102	Max Storage (scf)	0	0	0	0	0	0	0	0	0	0	0
103	Design daily NG demand (scf)	0	0	0	0	0	0	0	0	0	0	0
104	Min. Comp. HP	3	3	3	3	3	3	3	3	3	3	3
105	Cycle Time (min)	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440
106	Number of Hoses	1	1	1	1	1	1	1	1	1	1	1
107	Autos per day	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
108	Auto NG per fill (scf)	537	537	537	537	537	537	537	537	537	537	537
109	Station Setup Cost Factor	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
110	Compressor Salvage Value						$0					
111	Storage Vessel Salvage Val.											
112	Dispenser Salvage Value											
113	Dryer Salvage Value											
114												
115	Labor Time Loss Calculations:											
116	Gasoline fill rate (gal/min)	7	7	7	7	7	7	7	7	7	7	7
117	Gasoline/diesel switch time (min)	3	3	3	3	3	3	3	3	3	3	3
118	Labor Cost ($/hour)	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
119	Number of Gasoline hoses	2	2	2	2	2	2	2	2	2	2	2
120	Number of Autos/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
121	Dedicated Gasoline Session Time	0	0	0	0	0	0	0	0	0	0	0
122												
123	OTHER FACTORS											
124	Work days/year											
125	Fast-fill onboard storage											
126	3000 psi comp factor											
127	100 psi comp factor											
128	Fuel in an "empty" tank (gal)											
129	NG to Gasoline Factor											
130	Station Maint cost/gas. gal. equiv.											
131	Electric cost ($/kWh)											
132	No. days off for tank recert.											
133	Discount Rate											
134	Tax Rate											
135	Beginning Period											
136	Vehicle Tax Deduction Value	1000	500	0	0	0	0	0	0	0	0	0
137	Infrastructure Tax Deduction Value	50000	25000	0	0	0	0	0	0	0	0	0

Figure 3-5 (5 of 6)

	A	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	Period	2014	2015	2016	2017	2018	2019	2020	2021	2022	End 2022	NPV
2	SAVINGS											
3	Gasoline Price Diff.	0	0	0	0	0	0	0	0	0	0	0
4	Vehicle Purchase Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
5	Infrastructure Tax Deduction	0	0	0	0	0	0	0	0	0	0	0
6	Maintenance	0	0	0	0	0	0	0	0	0	0	0
7												
8												
9												
10	Total Savings	0	0	0	0	0	0	0	0	0	0	0
11												
12	COSTS											
22	Vehicle											
23	Conversion Kit	0	0	0	0	0	0	0	0	0	0	0
24	Tanks	0	0	0	0	0	0	0	0	0	0	0
25	Labor	0	0	0	0	0	0	0	0	0	0	0
26	OEM	0	0	0	0	0	0	0	0	0	0	0
27	Subtotal	0	0	0	0	0	0	0	0	0	0	0
28												
29	Operating											
31	Cylinder Recert.	0	0	0	0	0	0	0	0	0	0	0
33	Labor - fueling time loss	0	0	0	0	0	0	0	0	0	0	0
34	NG Fuel Tax	0	0	0	0	0	0	0	0	0	0	0
35	Additional Training											
36	Subtotal	0	0	0	0	0	0	0	0	0	0	0
37												
38	Total Costs	0	0	0	0	0	0	0	0	0	0	0
39												
40	Savings - Cost	0	0	0	0	0	0	0	0	0	0	0
41	NPV	0	0	0	0	0	0	0	0	0	0	
42	NPV-cumulative	0	0	0	0	0	0	0	0	0	0	
43	Discount Factor	8.140	8.954	9.850	10.835	11.918	13.110	14.421	15.863	17.449	17.449	
44												
45	Benefit per vehicle per year											
47	VEHICLE DATA											
48	Automobiles:											
49	Number of Vehicles	0	0	0	0	0	0	0	0	0	0	
51	Number New Conversions											
53	Number Kits Transferred											
56	Number Conversions Retired											
57	Number OEM											
59	Number OEM Retired											
61	Number Vehicle Needing Recert.											
63	Gasoline MPG	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	
65	CNG MPG Adjust. Factor	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	
66	CNG MPG	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	
67	Dual-fuel MPG Adjust. Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	
68	Dual-Fuel Gasoline MPG	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	
70	Annual miles traveled per vehicle	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	
71	Annual NG consump (scf)	0	0	0	0	0	0	0	0	0	0	
72	Annual gasoline consump (gal)	0	0	0	0	0	0	0	0	0	0	
73	Conversion Kit Cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	
74	Conv. Kit Salvage Value	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	
75	Conv. labor cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	
76	Tank cost	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	
77	Tank Salvage Value	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
78	OEM Cost Difference	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	
79	OEM Salvage Value Difference	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	

Figure 3-5 (6 of 6)

	A	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	Period	2014	2015	2016	2017	2018	2019	2020	2021	2022	End 2022	NPV
80	Fuel Capacity/tank (scf)	600	600	600	600	600	600	600	600	600	600	
81	Number tanks/veh.	1	1	1	1	1	1	1	1	1	1	
82	Tank Recert. Cost/tank	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	
83	% NG miles	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
84	Maint. Cost Difference/year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
85	Annual NG Fuel Tax per vehicle	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120	
87	On-board gasoline capacity	16	16	16	16	16	16	16	16	16	16	
89	FUEL PRICES											
90	Natural Gas Price/mcf	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	$5.785	
91	Gasoline Price/gallon	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	$1.100	
92	NG price/gallon gasoline equivalent	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	$0.710	
93	Annual Fuel Price Adjustment											
94	Total NG consump (scf)	0	0	0	0	0	0	0	0	0	0	
95												
96	STATION DESIGN											
97	Useable Storage	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	
98	Switch Time (min.)	3	3	3	3	3	3	3	3	3	3	
99	NG Session Time (min.)	0	0	0	0	0	0	0	0	0	0	
100	Flow Rate/hose (scfm)	500	500	500	500	500	500	500	500	500	500	
101	Min. Comp. Size (scfm)	0	0	0	0	0	0	0	0	0	0	
102	Max Storage (scf)	0	0	0	0	0	0	0	0	0	0	
103	Design daily NG demand (scf)	0	0	0	0	0	0	0	0	0	0	
104	Min. Comp. HP	3	3	3	3	3	3	3	3	3	3	
105	Cycle Time (min)	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	
106	Number of Hoses	1	1	1	1	1	1	1	1	1	1	
107	Autos per day	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
108	Auto NG per fill (scf)	537	537	537	537	537	537	537	537	537	537	
109	Station Setup Cost Factor	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	
110	Compressor Salvage Value										$0	
111	Storage Vessel Salvage Val.										$0	
112	Dispenser Salvage Value										$0	
113	Dryer Salvage Value										$0	
114												
115	Labor Time Loss Calculations:											
116	Gasoline fill rate (gal/min)	7	7	7	7	7	7	7	7	7	7	
117	Gasoline/diesel switch time (min)	3	3	3	3	3	3	3	3	3	3	
118	Labor Cost ($/hour)	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	
119	Number of Gasoline hoses	2	2	2	2	2	2	2	2	2	2	
120	Number of Autos/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
121	Dedicated Gasoline Session Time	0	0	0	0	0	0	0	0	0	0	
122												
123	OTHER FACTORS											
124	Work days/year											
125	Fast-fill onboard storage											
126	3000 psi comp factor											
127	100 psi comp factor											
128	Fuel in an "empty" tank (gal)											
129	NG to Gasoline Factor											
130	Station Maint cost/gas. gal. equiv.											
131	Electric cost ($/kWh)											
132	No. days off for tank recert.											
133	Discount Rate											
134	Tax Rate											
135	Beginning Period											
136	Vehicle Tax Deduction Value	0	0	0	0	0	0	0	0	0	0	
137	Infrastructure Tax Deduction Value	0	0	0	0	0	0	0	0	0	0	

Figure 3-6
Public Refueling Model Variables and Cell References

Variable Name	Spreadsheet Cell Reference
Annual.Fuel.Price.Adjustment	=$B$93
Auto.Annual.gasoline.consump.gal	=$B$72:$AH$72
Auto.Annual.NG.consump.scf	=$B$71:$AH$71
Auto.Annual.NG.Fuel.Tax	=$B$85:AF$85
Auto.CNG.mpg	=$B$66:$AH$66
Auto.CNG.MPG.Adj.Factor	=$B$65:$AH$65
Auto.Conv.Kit.Cost	=$B$73:$AH$73
Auto.Conv.Kit.Salvage.Value	=$B$74:$AH$74
Auto.Conv.lab.cost	=$B$75:$AH$75
Auto.Dual.Fuel.Gasoline.MPG	=$B$68:$AH$68
Auto.Dual.fuel.MPG.Adjust.Factor	=$B$67:$AH$67
Auto.Fuel.Capacity.scf	=$B$80:$AH$80
Auto.Gasoline.MPG	=$B$63:$AH$63
Auto.Maint.Cost.Diff	=$B$84:$AH$84
Auto.miles	=$B$70:$AH$70
Auto.NG.per.fill.scf	=$B$108:$AH$108
Auto.Num.CNG.Converted	=$B$51:$AH$51
Auto.Num.CNG.Retired	=$B$55:$AH$55
Auto.Num.CNG.Trans	=$B$53:$AH$53
Auto.Num.Need.Recert	=$B$61:$AH$61
Auto.Num.OEM	=$B$57:$AH$57
Auto.Num.OEM.Retired	=$B$59:$AH$59
Auto.Num.Vehicles	=$B$49:$AH$49
Auto.OEM.Cost.Diff	=$B$78:$AH$78
Auto.OEM.Salvage.Value	=$B$79:$AH$79
Auto.On.board.gasoline.capacity	=$A$87:$AH$87
Auto.Prcnt.NG.miles	=$B$83:$AH$83
Auto.Tank.cost	=$B$76:$AH$76
Auto.Tank.Recert.Cost	=$B$82:$AH$82
Auto.Tank.Salvage.Value	=$B$77:$AH$77
Auto.tanks.per.veh.	=$B$81:$AH$81
Autos.per.day	=$B$107:$AH$107
Beginning.Period	=$B$135
Compressor.Salvage.Value	=$B$110:$AH$110
Conversion.Kit.costs	=$B$23:$AH$23
Cost.per.veh.per.year	=$B$45
Cumulative.NPV	=$AI$40
Cycle.Time	=$B$105:$AH$105
Days.off.tank.recert	=$B$132
Ded.Gasoline.Session.Time	=$B$121:$AH$121

Variable Name	Spreadsheet Cell Reference
Design.Daily.NG.demand.scf	=$B$103:$AH$103
Discount.Rate	=$B$133
Dispenser.Salvage.Value	=$B$112:$AH$112
Dryer.Salvage.Value	=$B$113:$AH$113
Electric.cost.kwh	=$B$131
Fast.fill.onboard.storage	=$B$125
Flow.Rate.hose.scfm	=$B$100:$AH$100
Fuel.in.empty.tank.gal	=$B$128
Fuel.Price.Diff.	=$B$3
Gasoline.diesel.switch.time	=$B$117:$AH$117
Gasoline.fill.rate.gal.min	=$B$116:$AH$116
Gasoline.Price.gallon	=$B$91:$AH$91
Infrastructure.Tax.Deduction.Value	=$A$137:$AH$137
Labor.Cost.hour	=$B$118:$AH$118
Labor.costs	=$B$25:$AH$25
Max.Storage.scf	=$B$102:$AH$102
Min.Comp.HP	=$B$104:$AH$104
Min.Comp.Size.scfm	=$B$101:$AH$101
Natural.Gas.Price.mcf	=$B$90:$AH$90
NG.Gasoline.Factor	=$B$129
NG.price.gallon.gasoline.equivalent	=$B$92:$AH$92
NG.Session.Time.min	=$B$99:$AH$99
Number.Autos.day	=$B$120:$AH$120
Number.Gasoline.hoses	=$B$119:$AH$119
Number.of.Hoses	=$B$106:$AH$106
OEM.costs	=$B$26:$AH$26
Period	=$A$1:$AH$1
Station.Maint.cost.gale	=$B$130
Station.Setup.Cost.Factor	=$B$109:$AH$109
Storage.Vessel.Salv.Val	=$B$111:$AH$111
Switch.Time.min	=$B$98:$AH$98
Tank.fill.factor.100psi	=$B$127
Tank.fill.factor.3000psi	=$B$126
Tanks.costs	=$B$24:$AH$24
Tax_Rate	=$B$134
Total.NG.consump.scf	=$B$94:$AH$94
Useable.Storage	=$B$97:$AH$97
Vehicle.Tax.Deduction.Value	=$A$136:$AH$136
Work.days.year	=$B$124

IV. ANALYSIS OF CNG FOR TAXI OPERATIONS

OVERVIEW

In place of monitoring actual CNG taxi operations through a demonstration project, the model presented in Section III will be used to evaluate the cost-effectiveness of CNG for taxis. Three different-sized fleets are used for this analysis: Small - 5 vehicles, Medium - 25 vehicles, and Large - 50 vehicles. The scenarios studied include a base case, the Internal Rate of Return for the base case, changes in maintenance savings (assumed zero for the base case), an original equipment manufacturer (OEM) price decrease to $1,200, no OEM's available now or in the future, the break-even price for gasoline, the break-even price for natural gas, and the minimum distance (miles/kilometers) traveled per vehicle to break even. A final scenario depicting the use of public refueling stations is also presented.

THE BASE CASE

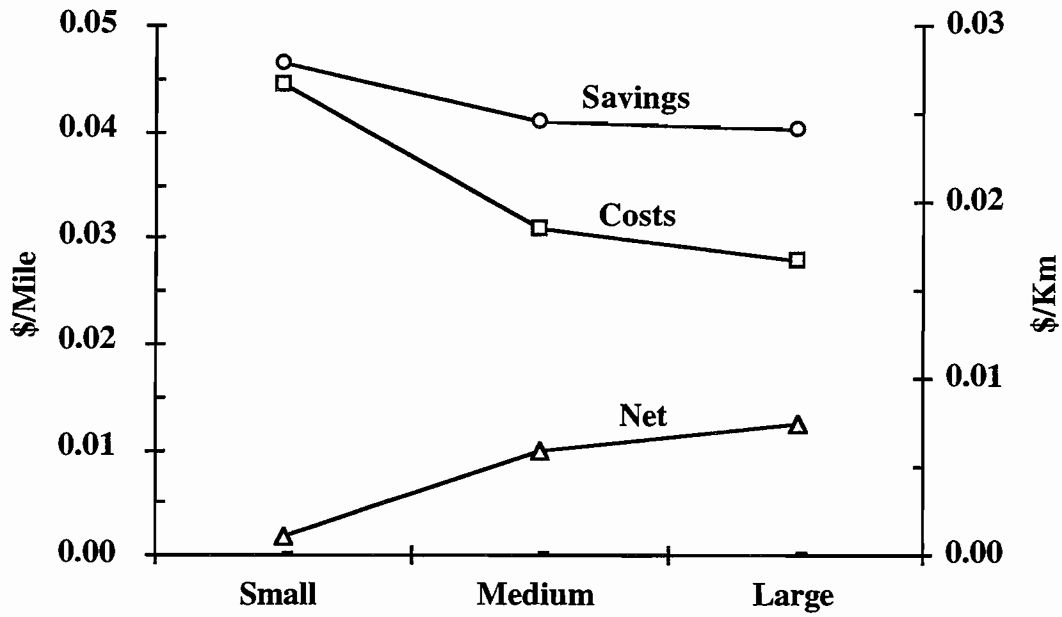
The base case uses the assumptions described in Section III. The results for the three fleet sizes are summarized in Table 4-1. Appendix A provides a more detailed summary of the savings and cost components for each of the fleets.

Table 4-1
Base Case

	Small Fleet	Medium Fleet	Large Fleet
Savings	$218,474	$962,656	$1,890,312
Costs	- $210,221	- $729,776	- $1,312,243
30-Year NPV	$8,254	$232,880	$578,069
Incremental Benefit per Vehicle	$175	$988	$1,226

The net present value (NPV) increases with fleet size, although with diminishing returns, as illustrated in Figure 4-1. The incremental savings per mile (kilometer) of operation decreases because of the $100,000 limit on the tax deduction for infrastructure. The smallest fleet is unable to receive the maximum benefit from this deduction because of its lower infrastructure cost. After the $100,000 limit is reached, a decrease in savings per vehicle mile (vehicle kilometer) continues because the growth in the number of vehicles reduces the value of the fixed benefit. Costs per vehicle mile continue to decrease with the growth in the number of vehicles, due to infrastructure economies of scale and wider distribution of some fixed costs.

Figure 4-1
Incremental Savings/Costs for Base Case



Internal Rate of Return

According to the base case assumptions, the discount rate was adjusted to yield a NPV of zero to determine the Internal Rate of Return for each fleet size. The results are summarized in Table 4-2 and detailed in Appendix B. The rate of return is highest for the largest fleet, but the rate of increase declines as the fleet size grows.

Table 4-2
Internal Rate of Return for Base Case

Small Fleet	11.4%
Medium Fleet	22.5%
Large Fleet	30.0%

Break-Even Fuel Prices

As demonstrated in Table 4-3, slight changes in the base price of fuels [$1.10/gallon ($0.29/L) for gasoline and $3.09/mcf ($0.09/m^3) for natural gas] affect the cost-effectiveness of the CNG operation. (Appendix C and D contain the detailed summaries for the break-even gasoline price and natural gas price, respectively.) A 4¢/gallon (1¢/L) change in the price of gasoline means the difference of a profitable CNG venture for the Small Fleet. The price of fuel becomes less sensitive as the fleet grows in size.

Table 4-3
Break-even Fuel Prices

	Gasoline[1]	Natural Gas[2]
Small Fleet	$1.06/gallon ($0.28/L)	$3.39/mcf ($0.10/m^3)
Medium Fleet	$0.90/gallon ($0.24/L)	$4.82/mcf ($0.15/m^3)
Large Fleet	$0.85/gallon ($0.22/L)	$5.23/mcf ($0.16/m^3)

[1] Assumes a natural gas price of $3.09/mcf ($0.09/m^3).
[2] Assumes a gasoline price of $1.10/gallon ($0.29/L).

Break-Even Miles of Travel

Previous research has demonstrated that CNG mileage must be high for a cost-effective operation. The Clean Air Cab owner estimates 60,000 miles (96,600 km) annually to break even. The final base case scenario determines the minimum number of miles (kilometers) traveled for cost-effectiveness. [The base case assumes that the taxi will travel 100,000 miles (161,000 km) a year.] The results for the three fleet sizes are summarized in Table 4-4 and detailed in Appendix E. In a manner similar to that for fuel price, the Small Fleet is particularly sensitive to small changes in vehicle miles of travel. The larger fleets can reduce their distance of operation and remain cost-effective.

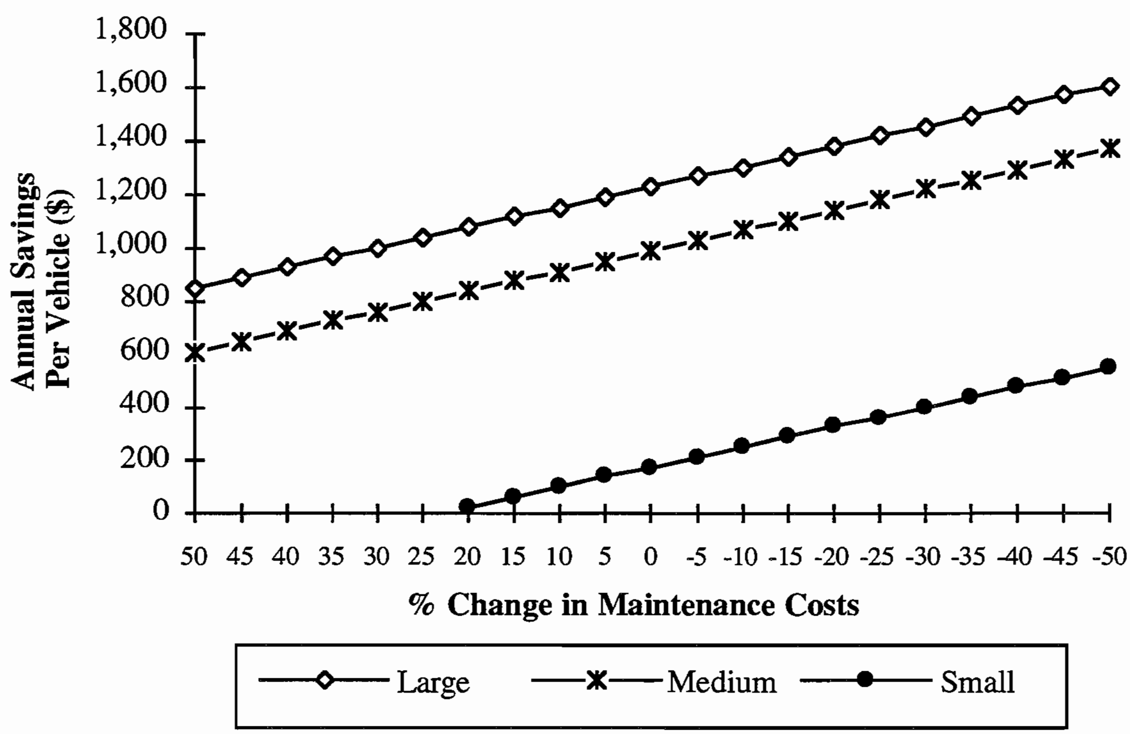
Table 4-4
Minimum Distance Traveled for Cost-Effectiveness

Small Fleet	83,586 miles	(134,573 km)
Medium Fleet	35,769 miles	(57,588 km)
Large Fleet	30,193 miles	(48,611 km)

MAINTENANCE SAVINGS

Many fleet operators have reported reductions in routine maintenance costs for natural gas vehicles. Because natural gas burns cleaner, it should require fewer oil and spark plug changes. Additionally, it should be less destructive to the exhaust system. The actual savings associated with natural gas operations are variable. Some studies have even reported maintenance cost increases. The base case assumed that there would be no change in maintenance savings. Figure 4-2 demonstrates that, for the Large and Medium Fleets, increases in maintenance costs by 50 percent do not offset the savings generated by the fuel price differential. The Small Fleet, on the other hand, begins to lose money if maintenance costs are increased by more than 20 percent.

Figure 4-2
Impact of Changes in Maintenance Costs



OEM VEHICLES

Currently, OEM CNG vehicles are not widely available. Moreover, for the few models that are produced, the costs are quite high. The automotive manufacturing industry has been hesitant to invest in large-scale production of alternative fuel vehicles. This is an important concern because the dedicated OEM CNG vehicle has higher fuel efficiency than the conventional dual-fuel conversion. Given the uncertainty of OEM, three sensitivity tests were conducted. The first test assumes that OEM's will not be available for the next 30 years. Taxi operators will have to convert new vehicles to CNG. The results of this scenario are summarized in Table 4-5 and documented in more detail in Appendix F. This scenario assumes that the storage tank and conversion kit have a life of 400,000 miles (643,600 km) and can be transferred from old to new vehicles, as in the base case.

For all three fleets, the results of the scenario with no OEM vehicles are worse than those of the base case. Although vehicle costs are reduced in the No OEM Scenario, this is more than offset by the reduction in fuel savings and the higher infrastructure and station operating costs. These offsets are a result of the lower fuel efficiency of the converted vehicle compared to the OEM dedicated vehicle.

Table 4-5
No OEM Scenario

	Small Fleet	Medium Fleet	Large Fleet
Savings	$204,719	$893,880	$1,752,759
Costs	- $213,888	- $744,993	- $1,341,900
30-Year NPV	- $9,169	$148,887	$410,859
Incremental Benefit per Vehicle	- $195	$632	$872

The results are even more alarming, if transferring conversion kits and storage cylinders is not feasible. Table 4-6 summarizes a scenario where every conversion requires a new conversion kit and storage cylinder. These results are presented in greater detail in Appendix G. Clearly, advances by the automobile manufacturers in production of dedicated CNG vehicles is important to the future success of taxi-CNG operations.

Table 4-6
No OEM's and No Kit/Tank Transfers

	Small Fleet	Medium Fleet	Large Fleet
Savings	$209,758	$919,075	$1,803,149
Costs	- $233,740	- $844,255	- $1,540,424
30-Year NPV	- $23,982	$74,820	$262,725
Incremental Benefit per Vehicle	- $509	$317	$557

If the automobile manufacturers do introduce large-scale production of dedicated natural gas vehicles, then, in addition to the increased supply available for use, economies of scale should lower the purchase price of the OEM. This scenario is depicted in Appendix H and summarized in Table 4-7. The scenario assumes that the OEM price is lowered from $2,500 to $1,200. The results are as expected.

Table 4-7
Reduced OEM Purchase Price

	Small Fleet	Medium Fleet	Large Fleet
Savings	$218,474	$962,656	$1,890,312
Costs	- $188,917	- $623,257	- $1,099,205
30-Year NPV	$29,557	$339,399	$791,107
Incremental Benefit per Vehicle	$627	$1,440	$1,678

PUBLIC REFUELING

Given the significant capital requirements for development of private fueling infrastructure, some taxi operators may opt for using public refueling stations, if available. The price per fuel paid at a public fueling station will be higher than that at the private station. A natural gas price of $0.71 per gallon of gasoline equivalent ($0.19/L) is used in this scenario. The results of the model run are shown in Table 4-8 and detailed in Appendix I. Public refueling does not allow larger fleets the benefits of economies of scale provided by owning one's own infrastructure. The incremental benefit is the same for all fleets, regardless of size. In order to be cost-effective, gasoline must remain about 28¢/gallon (7.4¢/L) higher than a gallon (liter) equivalent of natural gas.

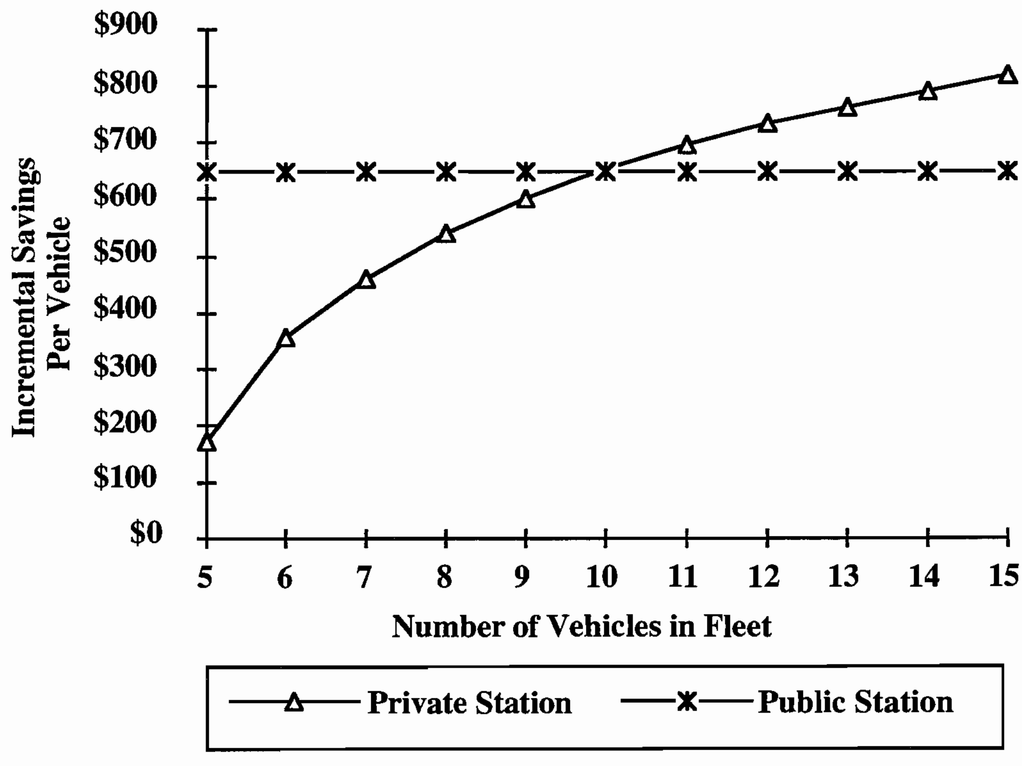
Table 4-8
Public Refueling Scenario

	Small Fleet	Medium Fleet	Large Fleet
Savings	$112,905	$564,523	$1,129,045
Costs	- $82,255	- $411,274	- $822,548
30-Year NPV	$30,650	$153,249	$306,497
Incremental Benefit per Vehicle	$650	$650	$650

V. CONCLUSIONS

The objectives of the study, as indicated in Section I, were to determine the cost-effectiveness of CNG for taxi operations and identify the energy savings associated with their operation. The cost-effectiveness of taxi CNG operations was presented in the previous section. In general, small fleets should utilize public refueling and then, when they reach a certain number of vehicles, construct their own private refueling facility. Using the NPV model presented in Section III and Section IV, a fleet operator should develop his/her facility when the fleet size reaches 10 or more vehicles. The relationship of the incremental benefits per vehicle by fleet size for public refueling and those for privately-owned refueling is illustrated in Figure 5-1.

Figure 5-1
Comparison of Public and Private Stations
by Fleet Size



The second objective of the study was to quantify fuel savings of a CNG taxi operation. Based on the presented model parameters, CNG taxis would save 5,263 gallons (19,920 L) of gasoline annually.

While CNG may not be cost-effective for many low-mileage applications, it is a viable option in urban taxi operations. Economically, it is a sound strategy for large taxi operations. Moreover, it provides additional air quality benefits through reduced emissions, and promotes the use of a vast Texas resource.

REFERENCES

American Gas Association (AGA). An Analysis of the Economic and Environmental Effects of Natural Gas as an Alternative Fuel, EA 1989-10, December 15, 1989.

Blazek, Chris. Institute of Gas Technology (personal communication for Taylor et al, 1991).

Canadian Resourcecon (1983) Limited. Final Report: Use of Natural Gas by Black Top Cabs, Vancouver, B.C., Report TE-85-4, Transportation Energy Division, Energy, Mines, and Resources, Canada, April 1985.

Christy Park, Inc. Seamless Pressure Vessels (brochure), McKeesport, Pennsylvania.

Davis, Stacy C., and Sonja G. Strange. Transportation Energy Data Book: Edition 13, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 1993.

DeLuchi, Mark A., Robert A. Johnston, and Daniel Sperling. "Methanol vs. Natural Gas Vehicles: A Comparison of Resource Supply, Performance, Emissions, Fuel Storage, Safety, Costs, and Transitions," SAE Paper 881656, 1988.

DeShazo, Starek, & Tang, Inc. and Houston Advanced Research Center. "Alternative Fuels and Vehicles Workshop," February 2, 1993 (Notebook).

Energy Information Administration (EIA), U.S. Department of Energy. Annual Energy Review 1992, Washington, D.C., June 1993.

Environmental Protection Agency (EPA). Analysis of the Economic and Environmental Effects of Compressed Natural Gas as a Vehicle Fuel, Vol I, Passenger Cars and Light Trucks, April 1990.

Environmental Protection Agency (EPA). Technical Report: Emissions, Fuel Economy, and Performance of Light-Duty CNG and Dual-Fuel Vehicles, EPA-AA-CTAB-88-05, June 1988.

Environmental Protection Agency (EPA), Office of Air Quality. National Air Quality and Emissions Trends Report, 1991, 450-R-92-001, Research Triangle Park, North Carolina, October 1992.

Euritt, Mark A., Dean B. Taylor, and Hani Mahmassani. Cost-Effectiveness Analysis of TxDOT CNG Fleet Conversion: Volume I, Research Report 983-2/1, Center for Transportation Research, The University of Texas at Austin, August 1992.

Euritt, Mark A., Dean B. Taylor, and Hani Mahmassani. Cost-Effectiveness Analysis of TxDOT LPG Fleet Conversion: Volume I, Research Report 983-4/1, Center for Transportation Research, The University of Texas at Austin, October 1992.

Funk, Paul. Western Sales and Testing of Deer Park, Inc., Deer Park, Texas (personal communication for Taylor et al, 1991).

General Accounting Office (GAO). Alternative Fuels: Experiences of Brazil, Canada, and New Zealand in Using Alternative Motor Fuels, GAO/RCED-92-119, Washington, D.C., May 1992.

Hitchcock, David. "City Fleet Use of Compressed Natural Gas -- Scottsdale, Arizona," Alternative Fuels Transportation Briefs, No. 3-7, Houston Advanced Research Center, April 1992.

Hitchcock, David. "Compressed Natural Gas School Bus Operations: Garland Independent School District," Alternative Fuels Transportation Briefs, No. 3-2, Houston Advanced Research Center, January 1991.

Hitchcock, David. "Governor's Energy Office Projects," Alternative Fuels Transportation Briefs, No. 3-10, Houston Advanced Research Center, April 1993.

Hitchcock, David. "Texas Alternative Fuels Legislation -- SB 740 and SB 769," Alternative Fuels Transportation Briefs, No. 1-1, Houston Advanced Research Center, February 1991.

Hitchcock, David. "The Energy Policy Act of 1992," Alternative Fuels Transportation Briefs, No. 1-6, Houston Advanced Research Center, July 1993.

Hitchcock, David. "Tulsa School Fleet Operates Dedicated CNG Buses," Alternative Fuels Transportation Briefs, No. 3-9, Houston Advanced Research Center, April 1992.

Hitchcock, David. "1993 Texas Alternative Fuels Legislation: Senate Bills 737 and Senate Bill 7," Alternative Fuels Transportation Briefs, No. 1-5, Houston Advanced Research Center, June 1993.

International Association for Natural Gas Vehicles (IANGV). Natural Gas Vehicles 1990, January 1990.

Osgoode, Larry. Phillips 66, Bartlesville, Oklahoma (personal communication for Taylor et al, 1991).

Pearson, Stan, and Terry Pearson. Tri-Fuels, Inc., Baton Rouge, Louisiana (personal communication for Taylor et al, 1991).

Petsinger, Robert. CNG Services of Pittsburgh, Inc., Pittsburgh, Pennsylvania (personal communication for Taylor et al, 1991).

Sharp, John. Motor Fuels Tax, #96-192, Texas Comptroller of Public Accounts, May 1992.

Slack, Gordon. Henderson, Inc., Garland, Texas (personal communication for Taylor et al, 1991).

State of Texas Energy Policy Partnership. STEPP: Volume II, Committee Reports, Austin, Texas, March 1993.

Taylor, Dean, Mark Euritt, and Hani Mahmassani. Documentation for CNG Fleet Conversion Cost-Effectiveness Model, Research Report 983-1, Center for Transportation Research, The University of Texas at Austin, December 1991.

Taylor, Dean, Mark Euritt, and Hani Mahmassani. "Economic Evaluation of Compressed Natural Gas Fleet Conversion and Operation," in Transportation Research Record, No. 1366, Transportation Research Board, National Research Council, Washington, D.C., 1992.

Texas Department of Transportation (TxDOT). Specification No. SDHPT-070-99-20, June 1990.

The Clean Fuels Report, Vol 5, No. 4, J. E. Sinor Consultants, Inc., Niwot, Colorado, September 1993.

U.S. Department of Energy (USDOE). Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Technical Report Four: Vehicle and Fuel Distribution Requirements, DOE/PE/0095P, Washington, D.C., August 1990.

U.S. Department of Energy (USDOE), Office of Energy Demand Policy. Final Report of the Interagency Commission on Alternative Motor Fuels, DOE/EP-0002P, Washington, D.C., September 1992.

APPENDIX A

NPV TAXI COST-EFFECTIVENESS MODEL
BASE CASE

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$175,964	80.5%	$0.0373
Vehicle Tax Deduction	$9,567	4.4%	$0.0020
Station Tax Deduction	$32,943	15.1%	$0.0070
Maintenance	$0	0.0%	$0.0000
Total Savings	$218,474	100.0%	$0.0464

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($17,823)	8.5%	($0.0038)
Compressor	($22,108)	10.5%	($0.0047)
Storage Vessels	($22,739)	10.8%	($0.0048)
Dispenser	($24,857)	11.8%	($0.0053)
Dryer	($9,943)	4.7%	($0.0021)
Subtotal	($97,469)	46.4%	($0.0207)
Vehicle			
Conversion Kit	($4,379)	2.1%	($0.0009)
Tanks	($5,000)	2.4%	($0.0011)
Labor	($8,757)	4.2%	($0.0019)
OEM	($38,255)	18.2%	($0.0081)
Subtotal	($56,391)	26.8%	($0.0120)
Operating			
Station Maint.	($9,863)	4.7%	($0.0021)
Cylinder Recert.	($171)	0.1%	$0.0000
Power	($20,634)	9.8%	($0.0044)
Labor - fuel time loss	($20,037)	9.5%	($0.0043)
NG Fuel Tax	($5,656)	2.7%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($56,361)	26.8%	($0.0120)
Total Costs	($210,221)	100.0%	($0.0446)
Savings - Cost	$8,254	N/A	$0.0018

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	6
Year 1: Storage Size (scf)	21,946

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$175.11

Incremental Benefit/mile	$0.0018

Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$879,821	91.4%	$0.0373
Vehicle Tax Deduction	$47,835	5.0%	$0.0020
Station Tax Deduction	$35,000	3.6%	$0.0015
Maintenance	$0	0.0%	$0.0000
Total Savings	$962,656	100.0%	$0.0408

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($39,297)	5.4%	($0.0017)
Compressor	($36,349)	5.0%	($0.0015)
Storage Vessels	($91,857)	12.6%	($0.0039)
Dispenser	($24,857)	3.4%	($0.0011)
Dryer	($9,943)	1.4%	($0.0004)
Subtotal	($202,302)	27.7%	($0.0086)
Vehicle			
Conversion Kit	($21,895)	3.0%	($0.0009)
Tanks	($25,000)	3.4%	($0.0011)
Labor	($43,783)	6.0%	($0.0019)
OEM	($191,274)	26.2%	($0.0081)
Subtotal	($281,953)	38.6%	($0.0120)
Operating			
Station Maint.	($49,316)	6.8%	($0.0021)
Cylinder Recert.	($854)	0.1%	$0.0000
Power	($66,884)	9.2%	($0.0028)
Labor - fuel time loss	($100,187)	13.7%	($0.0043)
NG Fuel Tax	($28,281)	3.9%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($245,521)	33.6%	($0.0104)
Total Costs	($729,776)	100.0%	($0.0310)
Savings - Cost	$232,880	N/A	$0.0099

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

Annual Maintenance Savings	0%

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

STATION DESIGN	
Year 1: Compressor Size (scfm)	32
Year 1: Storage Size (scf)	87,294

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$988.15

Incremental Benefit/mile	$0.0099

Fleet Size
Large (50)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$1,759,642	93.1%	$0.0373
Vehicle Tax Deduction	$95,670	5.1%	$0.0020
Station Tax Deduction	$35,000	1.9%	$0.0007
Maintenance	$0	0.0%	$0.0000
Total Savings	$1,890,312	100.0%	$0.0401

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($52,429)	4.0%	($0.0011)
Compressor	($54,281)	4.1%	($0.0012)
Storage Vessels	($124,856)	9.5%	($0.0026)
Dispenser	($24,857)	1.9%	($0.0005)
Dryer	($9,943)	0.8%	($0.0002)
Subtotal	($266,366)	20.3%	($0.0057)
Vehicle			
Conversion Kit	($43,791)	3.3%	($0.0009)
Tanks	($50,000)	3.8%	($0.0011)
Labor	($87,566)	6.7%	($0.0019)
OEM	($382,549)	29.2%	($0.0081)
Subtotal	($563,905)	43.0%	($0.0120)
Operating			
Station Maint.	($98,633)	7.5%	($0.0021)
Cylinder Recert.	($1,708)	0.1%	$0.0000
Power	($124,696)	9.5%	($0.0026)
Labor - fuel time loss	($200,374)	15.3%	($0.0043)
NG Fuel Tax	($56,561)	4.3%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($481,971)	36.7%	($0.0102)
Total Costs	($1,312,243)	100.0%	($0.0278)
Savings - Cost	$578,069	N/A	$0.0123

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	64
Year 1: Storage Size (scf)	118,493

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$1,226.42

Incremental Benefit/mile	$0.0123

APPENDIX B

NPV TAXI COST-EFFECTIVENESS MODEL INTERNAL RATE OF RETURN FOR BASE CASE

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$156,433	78.8%	$0.0372
Vehicle Tax Deduction	$9,029	4.6%	$0.0021
Station Tax Deduction	$32,943	16.6%	$0.0078
Maintenance	$0	0.0%	$0.0000
Total Savings	$198,405	100.0%	$0.0472

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($17,636)	8.9%	($0.0042)
Compressor	($21,525)	10.8%	($0.0051)
Storage Vessels	($22,955)	11.6%	($0.0055)
Dispenser	($24,903)	12.6%	($0.0059)
Dryer	($9,961)	5.0%	($0.0024)
Subtotal	($96,980)	48.9%	($0.0231)
Vehicle			
Conversion Kit	($4,418)	2.2%	($0.0011)
Tanks	($5,000)	2.5%	($0.0012)
Labor	($8,613)	4.3%	($0.0020)
OEM	($32,851)	16.6%	($0.0078)
Subtotal	($50,882)	25.6%	($0.0121)
Operating			
Station Maint.	($8,844)	4.5%	($0.0021)
Cylinder Recert.	($162)	0.1%	$0.0000
Power	($18,455)	9.3%	($0.0044)
Labor - fuel time loss	($18,039)	9.1%	($0.0043)
NG Fuel Tax	($5,042)	2.5%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($50,543)	25.5%	($0.0120)
Total Costs	($198,405)	100.0%	($0.0472)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

Annual Maintenance Savings	0%

DISCOUNT RATE	11.4%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

STATION DESIGN	
Year 1: Compressor Size (scfm)	6
Year 1: Storage Size (scf)	21,946

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$0.00

Incremental Benefit/mile	$0.0000

Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$404,889	85.8%	$0.0366
Vehicle Tax Deduction	$31,814	6.7%	$0.0029
Station Tax Deduction	$35,000	7.4%	$0.0032
Maintenance	$0	0.0%	$0.0000
Total Savings	$471,702	100.0%	$0.0426

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($38,016)	8.1%	($0.0034)
Compressor	($32,303)	6.8%	($0.0029)
Storage Vessels	($94,460)	20.0%	($0.0085)
Dispenser	($24,994)	5.3%	($0.0023)
Dryer	($9,998)	2.1%	($0.0009)
Subtotal	($199,770)	42.4%	($0.0180)
Vehicle			
Conversion Kit	($23,189)	4.9%	($0.0021)
Tanks	($25,000)	5.3%	($0.0023)
Labor	($38,594)	8.2%	($0.0035)
OEM	($63,884)	13.5%	($0.0058)
Subtotal	($150,666)	31.9%	($0.0136)
Operating			
Station Maint.	($24,179)	5.1%	($0.0022)
Cylinder Recert.	($555)	0.1%	($0.0001)
Power	($32,666)	6.9%	($0.0029)
Labor - fuel time loss	($50,573)	10.7%	($0.0046)
NG Fuel Tax	($13,293)	2.8%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($121,266)	25.7%	($0.0109)
Total Costs	($471,703)	100.0%	($0.0426)
Savings - Cost	$0	N/A	$0.0000

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VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	22.5%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	32
Year 1: Storage Size (scf)	87,294

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Cost/vehicle/year	$0.00
Incremental Cost/mile	$0.0000

Fleet Size
Large (50)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$603,456	87.1%	$0.0362
Vehicle Tax Deduction	$54,277	7.8%	$0.0033
Station Tax Deduction	$35,000	5.1%	$0.0021
Maintenance	$0	0.0%	$0.0000
Total Savings	$692,733	100.0%	$0.0416
COSTS		% of	Incremental
Infrastructure		Costs	Cost/Mile
Land	$0	0.0%	$0.0000
Station setup	($50,320)	7.3%	($0.0030)
Compressor	($47,632)	6.9%	($0.0029)
Storage Vessels	($128,515)	18.6%	($0.0077)
Dispenser	($24,999)	3.6%	($0.0015)
Dryer	($10,000)	1.4%	($0.0006)
Subtotal	($261,466)	37.7%	($0.0157)
Vehicle			
Conversion Kit	($47,307)	6.8%	($0.0028)
Tanks	($50,000)	7.2%	($0.0030)
Labor	($72,756)	10.5%	($0.0044)
OEM	($78,447)	11.3%	($0.0047)
Subtotal	($248,510)	35.9%	($0.0149)
Operating			
Station Maint.	($36,993)	5.3%	($0.0022)
Cylinder Recert.	($875)	0.1%	($0.0001)
Power	($46,655)	6.7%	($0.0028)
Labor - fuel time loss	($78,244)	11.3%	($0.0047)
NG Fuel Tax	($19,989)	2.9%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($182,758)	26.4%	($0.0110)
Total Costs	($692,733)	100.0%	($0.0416)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	30.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

STATION DESIGN	
Year 1: Compressor Size (scfm)	64
Year 1: Storage Size (scf)	118,493

Annual Maintenance Savings	0%

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$0.00

Incremental Benefit/mile	$0.0000

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APPENDIX C

NPV TAXI COST-EFFECTIVENESS MODEL BREAK-EVEN GASOLINE PRICE

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$167,711	79.8%	$0.0356
Vehicle Tax Deduction	$9,567	4.6%	$0.0020
Station Tax Deduction	$32,943	15.7%	$0.0070
Maintenance	$0	0.0%	$0.0000
Total Savings	$210,221	100.0%	$0.0446

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($17,823)	8.5%	($0.0038)
Compressor	($22,108)	10.5%	($0.0047)
Storage Vessels	($22,739)	10.8%	($0.0048)
Dispenser	($24,857)	11.8%	($0.0053)
Dryer	($9,943)	4.7%	($0.0021)
Subtotal	($97,469)	46.4%	($0.0207)
Vehicle			
Conversion Kit	($4,379)	2.1%	($0.0009)
Tanks	($5,000)	2.4%	($0.0011)
Labor	($8,757)	4.2%	($0.0019)
OEM	($38,255)	18.2%	($0.0081)
Subtotal	($56,391)	26.8%	($0.0120)
Operating			
Station Maint.	($9,863)	4.7%	($0.0021)
Cylinder Recert.	($171)	0.1%	$0.0000
Power	($20,634)	9.8%	($0.0044)
Labor - fuel time loss	($20,037)	9.5%	($0.0043)
NG Fuel Tax	($5,656)	2.7%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($56,361)	26.8%	($0.0120)
Total Costs	($210,221)	100.0%	($0.0446)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.06
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	6
Year 1: Storage Size (scf)	21,946

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Cost/vehicle/year	$0.00
Incremental Cost/mile	$0.0000

Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$646,941	88.6%	$0.0275
Vehicle Tax Deduction	$47,835	6.6%	$0.0020
Station Tax Deduction	$35,000	4.8%	$0.0015
Maintenance	$0	0.0%	$0.0000
Total Savings	$729,776	100.0%	$0.0310

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($39,297)	5.4%	($0.0017)
Compressor	($36,349)	5.0%	($0.0015)
Storage Vessels	($91,857)	12.6%	($0.0039)
Dispenser	($24,857)	3.4%	($0.0011)
Dryer	($9,943)	1.4%	($0.0004)
Subtotal	($202,302)	27.7%	($0.0086)
Vehicle			
Conversion Kit	($21,895)	3.0%	($0.0009)
Tanks	($25,000)	3.4%	($0.0011)
Labor	($43,783)	6.0%	($0.0019)
OEM	($191,274)	26.2%	($0.0081)
Subtotal	($281,953)	38.6%	($0.0120)
Operating			
Station Maint.	($49,316)	6.8%	($0.0021)
Cylinder Recert.	($854)	0.1%	$0.0000
Power	($66,884)	9.2%	($0.0028)
Labor - fuel time loss	($100,187)	13.7%	($0.0043)
NG Fuel Tax	($28,281)	3.9%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($245,521)	33.6%	($0.0104)
Total Costs	($729,776)	100.0%	($0.0310)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$0.90
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	32
Year 1: Storage Size (scf)	87,294

ASSUMPTIONS
1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Cost/vehicle/year	$0.00

Incremental Cost/mile	$0.0000

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Fleet Size
Large (50)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$1,181,573	90.0%	$0.0251
Vehicle Tax Deduction	$95,670	7.3%	$0.0020
Station Tax Deduction	$35,000	2.7%	$0.0007
Maintenance	$0	0.0%	$0.0000
Total Savings	$1,312,243	100.0%	$0.0278

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($52,429)	4.0%	($0.0011)
Compressor	($54,281)	4.1%	($0.0012)
Storage Vessels	($124,856)	9.5%	($0.0026)
Dispenser	($24,857)	1.9%	($0.0005)
Dryer	($9,943)	0.8%	($0.0002)
Subtotal	($266,366)	20.3%	($0.0057)
Vehicle			
Conversion Kit	($43,791)	3.3%	($0.0009)
Tanks	($50,000)	3.8%	($0.0011)
Labor	($87,566)	6.7%	($0.0019)
OEM	($382,549)	29.2%	($0.0081)
Subtotal	($563,905)	43.0%	($0.0120)
Operating			
Station Maint.	($98,633)	7.5%	($0.0021)
Cylinder Recert.	($1,708)	0.1%	$0.0000
Power	($124,696)	9.5%	($0.0026)
Labor - fuel time loss	($200,374)	15.3%	($0.0043)
NG Fuel Tax	($56,561)	4.3%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($481,971)	36.7%	($0.0102)
Total Costs	($1,312,243)	100.0%	($0.0278)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$0.85
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	64
Year 1: Storage Size (scf)	118,493

ASSUMPTIONS
1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$0.00

Incremental Benefit/mile	$0.0000

APPENDIX D

NPV TAXI COST-EFFECTIVENESS MODEL BREAK-EVEN NATURAL GAS PRICE

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$167,711	79.8%	$0.0356
Vehicle Tax Deduction	$9,567	4.6%	$0.0020
Station Tax Deduction	$32,943	15.7%	$0.0070
Maintenance	$0	0.0%	$0.0000
Total Savings	$210,221	100.0%	$0.0446
COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($17,823)	8.5%	($0.0038)
Compressor	($22,108)	10.5%	($0.0047)
Storage Vessels	($22,739)	10.8%	($0.0048)
Dispenser	($24,857)	11.8%	($0.0053)
Dryer	($9,943)	4.7%	($0.0021)
Subtotal	($97,469)	46.4%	($0.0207)
Vehicle			
Conversion Kit	($4,379)	2.1%	($0.0009)
Tanks	($5,000)	2.4%	($0.0011)
Labor	($8,757)	4.2%	($0.0019)
OEM	($38,255)	18.2%	($0.0081)
Subtotal	($56,391)	26.8%	($0.0120)
Operating			
Station Maint.	($9,863)	4.7%	($0.0021)
Cylinder Recert.	($171)	0.1%	$0.0000
Power	($20,634)	9.8%	($0.0044)
Labor - fuel time loss	($20,037)	9.5%	($0.0043)
NG Fuel Tax	($5,656)	2.7%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($56,361)	26.8%	($0.0120)
Total Costs	($210,221)	100.0%	($0.0446)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.39
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.42

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	6
Year 1: Storage Size (scf)	21,946

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Cost/vehicle/year	$0.00

Incremental Cost/mile	$0.0000

Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$646,941	88.6%	$0.0275
Vehicle Tax Deduction	$47,835	6.6%	$0.0020
Station Tax Deduction	$35,000	4.8%	$0.0015
Maintenance	$0	0.0%	$0.0000
Total Savings	$729,776	100.0%	$0.0310

COSTS		% of	Incremental
Infrastructure		Costs	Cost/Mile
Land	$0	0.0%	$0.0000
Station setup	($39,297)	5.4%	($0.0017)
Compressor	($36,349)	5.0%	($0.0015)
Storage Vessels	($91,857)	12.6%	($0.0039)
Dispenser	($24,857)	3.4%	($0.0011)
Dryer	($9,943)	1.4%	($0.0004)
Subtotal	($202,302)	27.7%	($0.0086)
Vehicle			
Conversion Kit	($21,895)	3.0%	($0.0009)
Tanks	($25,000)	3.4%	($0.0011)
Labor	($43,783)	6.0%	($0.0019)
OEM	($191,274)	26.2%	($0.0081)
Subtotal	($281,953)	38.6%	($0.0120)
Operating			
Station Maint.	($49,316)	6.8%	($0.0021)
Cylinder Recert.	($854)	0.1%	$0.0000
Power	($66,884)	9.2%	($0.0028)
Labor - fuel time loss	($100,187)	13.7%	($0.0043)
NG Fuel Tax	($28,281)	3.9%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($245,521)	33.6%	($0.0104)
Total Costs	($729,776)	100.0%	($0.0310)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$4.82
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.59

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	32
Year 1: Storage Size (scf)	87,294

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Cost/vehicle/year	$0.00

Incremental Cost/mile	$0.0000

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$1,181,573	90.0%	$0.0251
Vehicle Tax Deduction	$95,670	7.3%	$0.0020
Station Tax Deduction	$35,000	2.7%	$0.0007
Maintenance	$0	0.0%	$0.0000
Total Savings	$1,312,243	100.0%	$0.0278
COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($52,429)	4.0%	($0.0011)
Compressor	($54,281)	4.1%	($0.0012)
Storage Vessels	($124,856)	9.5%	($0.0026)
Dispenser	($24,857)	1.9%	($0.0005)
Dryer	($9,943)	0.8%	($0.0002)
Subtotal	($266,366)	20.3%	($0.0057)
Vehicle			
Conversion Kit	($43,791)	3.3%	($0.0009)
Tanks	($50,000)	3.8%	($0.0011)
Labor	($87,566)	6.7%	($0.0019)
OEM	($382,549)	29.2%	($0.0081)
Subtotal	($563,905)	43.0%	($0.0120)
Operating			
Station Maint.	($98,633)	7.5%	($0.0021)
Cylinder Recert.	($1,708)	0.1%	$0.0000
Power	($124,696)	9.5%	($0.0026)
Labor - fuel time loss	($200,374)	15.3%	($0.0043)
NG Fuel Tax	($56,561)	4.3%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($481,971)	36.7%	($0.0102)
Total Costs	($1,312,243)	100.0%	($0.0278)
Savings - Cost	$0	N/A	$0.0000

Fleet Size
Large (50)

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$5.23
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.64

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	64
Year 1: Storage Size (scf)	118,493

ASSUMPTIONS
1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$0.00

Incremental Benefit/mile	$0.0000

APPENDIX E

NPV TAXI COST-EFFECTIVENESS MODEL
MINIMUM MILEAGE FOR BREAK-EVEN

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$145,364	79.5%	$0.0369
Vehicle Tax Deduction	$6,308	3.5%	$0.0016
Station Tax Deduction	$31,077	17.0%	$0.0079
Maintenance	$0	0.0%	$0.0000
Total Savings	$182,750	100.0%	$0.0464
COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($16,734)	9.2%	($0.0042)
Compressor	($21,527)	11.8%	($0.0055)
Storage Vessels	($19,092)	10.4%	($0.0048)
Dispenser	($24,857)	13.6%	($0.0063)
Dryer	($9,943)	5.4%	($0.0025)
Subtotal	($92,152)	50.4%	($0.0234)
Vehicle			
Conversion Kit	($4,487)	2.5%	($0.0011)
Tanks	($5,000)	2.7%	($0.0013)
Labor	($8,415)	4.6%	($0.0021)
OEM	($21,777)	11.9%	($0.0055)
Subtotal	($39,679)	21.7%	($0.0101)
Operating			
Station Maint.	($8,448)	4.6%	($0.0021)
Cylinder Recert.	($171)	0.1%	$0.0000
Power	($19,191)	10.5%	($0.0049)
Labor - fuel time loss	($17,452)	9.5%	($0.0044)
NG Fuel Tax	($5,656)	3.1%	($0.0014)
Additional training	$0	0.0%	$0.0000
Subtotal	($50,919)	27.9%	($0.0129)
Total Costs	($182,750)	100.0%	($0.0464)
Savings - Cost	$0	N/A	$0.0000

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VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	83,586	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	5
Year 1: Storage Size (scf)	18,498

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$0.00

Incremental Benefit/mile	$0.0000

Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$311,029	83.5%	$0.0369
Vehicle Tax Deduction	$26,480	7.1%	$0.0031
Station Tax Deduction	$35,000	9.4%	$0.0042
Maintenance	$0	0.0%	$0.0000
Total Savings	$372,510	100.0%	$0.0442

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($22,825)	6.1%	($0.0027)
Compressor	($24,901)	6.7%	($0.0030)
Storage Vessels	($39,368)	10.6%	($0.0047)
Dispenser	($24,857)	6.7%	($0.0029)
Dryer	($9,943)	2.7%	($0.0012)
Subtotal	($121,894)	32.7%	($0.0145)
Vehicle			
Conversion Kit	($22,434)	6.0%	($0.0027)
Tanks	($25,000)	6.7%	($0.0030)
Labor	($25,000)	6.7%	($0.0030)
OEM	($63,150)	17.0%	($0.0075)
Subtotal	($135,584)	36.4%	($0.0161)
Operating			
Station Maint.	($18,077)	4.9%	($0.0021)
Cylinder Recert.	($854)	0.2%	($0.0001)
Power	($30,478)	8.2%	($0.0036)
Labor - fuel time loss	($37,342)	10.0%	($0.0044)
NG Fuel Tax	($28,281)	7.6%	($0.0034)
Additional training	$0	0.0%	$0.0000
Subtotal	($115,032)	30.9%	($0.0136)
Total Costs	($372,510)	100.0%	($0.0442)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	35,769	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	11
Year 1: Storage Size (scf)	37,668

ASSUMPTIONS
1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Cost/vehicle/year	$0.00
Incremental Cost/mile	$0.0000

Fleet Size
Large (50)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$521,987	85.8%	$0.0367
Vehicle Tax Deduction	$51,328	8.4%	$0.0036
Station Tax Deduction	$35,000	5.8%	$0.0025
Maintenance	$0	0.0%	$0.0000
Total Savings	$608,314	100.0%	$0.0427

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($29,880)	4.9%	($0.0021)
Compressor	($29,277)	4.8%	($0.0021)
Storage Vessels	($62,378)	10.3%	($0.0044)
Dispenser	($24,857)	4.1%	($0.0017)
Dryer	($9,943)	1.6%	($0.0007)
Subtotal	($156,335)	25.7%	($0.0110)
Vehicle			
Conversion Kit	($45,335)	7.5%	($0.0032)
Tanks	($50,000)	8.2%	($0.0035)
Labor	($50,000)	8.2%	($0.0035)
OEM	($106,647)	17.5%	($0.0075)
Subtotal	($251,982)	41.4%	($0.0177)
Operating			
Station Maint.	($30,810)	5.1%	($0.0022)
Cylinder Recert.	($2,990)	0.5%	($0.0002)
Power	($45,492)	7.5%	($0.0032)
Labor - fuel time loss	($64,143)	10.5%	($0.0045)
NG Fuel Tax	($56,561)	9.3%	($0.0040)
Additional training	$0	0.0%	$0.0000
Subtotal	($199,997)	32.9%	($0.0141)
Total Costs	($608,314)	100.0%	($0.0427)
Savings - Cost	$0	N/A	$0.0000

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	30,193	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	19
Year 1: Storage Size (scf)	59,423

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles:
200,000

Benefit/vehicle/year	$0.00

Incremental Benefit/mile	$0.0000

APPENDIX F

NPV TAXI COST-EFFECTIVENESS MODEL
NO OEM'S: KITS/TANKS 400,000 MILE USEFUL LIFE

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$164,618	80.4%	$0.0349
Vehicle Tax Deduction	$7,158	3.5%	$0.0015
Station Tax Deduction	$32,943	16.1%	$0.0070
Maintenance	$0	0.0%	$0.0000
Total Savings	$204,719	100.0%	$0.0434
COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($17,852)	8.3%	($0.0038)
Compressor	($22,220)	10.4%	($0.0047)
Storage Vessels	($22,739)	10.6%	($0.0048)
Dispenser	($24,857)	11.6%	($0.0053)
Dryer	($9,943)	4.6%	($0.0021)
Subtotal	($97,611)	45.6%	($0.0207)
Vehicle			
Conversion Kit	($12,235)	5.7%	($0.0026)
Tanks	($14,115)	6.6%	($0.0030)
Labor	($25,144)	11.8%	($0.0053)
OEM	$0	0.0%	$0.0000
Subtotal	($51,494)	24.1%	($0.0109)
Operating			
Station Maint.	($11,121)	5.2%	($0.0024)
Cylinder Recert.	($634)	0.3%	($0.0001)
Power	($22,889)	10.7%	($0.0049)
Labor - fuel time loss	($24,483)	11.4%	($0.0052)
NG Fuel Tax	($5,656)	2.6%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($64,783)	30.3%	($0.0137)
Total Costs	($213,888)	100.0%	($0.0454)
Savings - Cost	($9,169)	N/A	($0.0019)

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	100,000	$3,000	N/A

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	6
Year 1: Storage Size (scf)	21,946

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM's are not availble during the 30 year period.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Cost/vehicle/year	($194.53)

Incremental Cost/mile	($0.0019)

Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$823,092	92.1%	$0.0349
Vehicle Tax Deduction	$35,788	4.0%	$0.0015
Station Tax Deduction	$35,000	3.9%	$0.0015
Maintenance	$0	0.0%	$0.0000
Total Savings	$893,880	100.0%	$0.0379
COSTS		% of	Incremental
Infrastructure		Costs	Cost/Mile
Land	$0	0.0%	$0.0000
Station setup	($39,445)	5.3%	($0.0017)
Compressor	($36,919)	5.0%	($0.0016)
Storage Vessels	($91,857)	12.3%	($0.0039)
Dispenser	($24,857)	3.3%	($0.0011)
Dryer	($9,943)	1.3%	($0.0004)
Subtotal	($203,021)	27.3%	($0.0086)
Vehicle			
Conversion Kit	($61,173)	8.2%	($0.0026)
Tanks	($70,575)	9.5%	($0.0030)
Labor	($125,720)	16.9%	($0.0053)
OEM	$0	0.0%	$0.0000
Subtotal	($257,469)	34.6%	($0.0109)
Operating			
Station Maint.	($55,603)	7.5%	($0.0024)
Cylinder Recert.	($3,171)	0.4%	($0.0001)
Power	($75,035)	10.1%	($0.0032)
Labor - fuel time loss	($122,414)	16.4%	($0.0052)
NG Fuel Tax	($28,281)	3.8%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($284,504)	38.2%	($0.0121)
Total Costs	($744,993)	100.0%	($0.0316)
Savings - Cost	$148,887	N/A	$0.0063

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	100,000	$3,000	N/A

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	32
Year 1: Storage Size (scf)	87,294

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM's are not availble during the 30 year period.
3. Automobiles are sold off at the end of the year when they reach the following number of miles:
   200,000

Benefit/vehicle/year	$631.75

Incremental Benefit/mile	$0.0063

Fleet Size
Large (50)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$1,646,183	93.9%	$0.0349
Vehicle Tax Deduction	$71,576	4.1%	$0.0015
Station Tax Deduction	$35,000	2.0%	$0.0007
Maintenance	$0	0.0%	$0.0000
Total Savings	$1,752,759	100.0%	$0.0372

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($52,727)	3.9%	($0.0011)
Compressor	($55,426)	4.1%	($0.0012)
Storage Vessels	($124,856)	9.3%	($0.0026)
Dispenser	($24,857)	1.9%	($0.0005)
Dryer	($9,943)	0.7%	($0.0002)
Subtotal	($267,809)	20.0%	($0.0057)
Vehicle			
Conversion Kit	($122,347)	9.1%	($0.0026)
Tanks	($141,150)	10.5%	($0.0030)
Labor	($251,441)	18.7%	($0.0053)
OEM	$0	0.0%	$0.0000
Subtotal	($514,937)	38.4%	($0.0109)
Operating			
Station Maint.	($111,205)	8.3%	($0.0024)
Cylinder Recert.	($6,343)	0.5%	($0.0001)
Power	($140,216)	10.4%	($0.0030)
Labor - fuel time loss	($244,828)	18.2%	($0.0052)
NG Fuel Tax	($56,561)	4.2%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($559,154)	41.7%	($0.0119)
Total Costs	($1,341,900)	100.0%	($0.0285)
Savings - Cost	$410,859	N/A	$0.0087

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	100,000	$3,000	N/A

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

Annual Maintenance Savings	0%

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

STATION DESIGN	
Year 1: Compressor Size (scfm)	64
Year 1: Storage Size (scf)	118,493

ASSUMPTIONS
1. Fueling station is designed for continuous fast-filling.
2. OEM's are not availble during the 30 year period.
3. Automobiles are sold off at the end of the year when they reach the following number of miles:
200,000

Benefit/vehicle/year	$871.67

Incremental Benefit/mile	$0.0087

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APPENDIX G

NPV TAXI COST-EFFECTIVENESS MODEL
NO OEM'S: KITS/TANKS 200,000 MILE USEFUL LIFE

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$164,618	78.5%	$0.0349
Vehicle Tax Deduction	$12,197	5.8%	$0.0026
Station Tax Deduction	$32,943	15.7%	$0.0070
Maintenance	$0	0.0%	$0.0000
Total Savings	$209,758	100.0%	$0.0445
COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($17,852)	7.6%	($0.0038)
Compressor	($22,220)	9.5%	($0.0047)
Storage Vessels	($22,739)	9.7%	($0.0048)
Dispenser	($24,857)	10.6%	($0.0053)
Dryer	($9,943)	4.3%	($0.0021)
Subtotal	($97,611)	41.8%	($0.0207)
Vehicle			
Conversion Kit	($21,058)	9.0%	($0.0045)
Tanks	($25,144)	10.8%	($0.0053)
Labor	($25,144)	10.8%	($0.0053)
OEM	$0	0.0%	$0.0000
Subtotal	($71,346)	30.5%	($0.0151)
Operating			
Station Maint.	($11,121)	4.8%	($0.0024)
Cylinder Recert.	($634)	0.3%	($0.0001)
Power	($22,889)	9.8%	($0.0049)
Labor - fuel time loss	($24,483)	10.5%	($0.0052)
NG Fuel Tax	($5,656)	2.4%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($64,783)	27.7%	($0.0137)
Total Costs	($233,740)	100.0%	($0.0496)
Savings - Cost	($23,982)	N/A	($0.0051)

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	100,000	$3,000	N/A

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	6
Year 1: Storage Size (scf)	21,946

ASSUMPTIONS
1. Fueling station is designed for continuous fast-filling.
2. OEM's are not availble during the 30 year period.
3. Automobiles are sold off at the end of the year when they reach the following number of miles:
200,000

Cost/vehicle/year	($508.81)

Incremental Cost/mile	($0.0051)

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Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$823,092	89.6%	$0.0349
Vehicle Tax Deduction	$60,983	6.6%	$0.0026
Station Tax Deduction	$35,000	3.8%	$0.0015
Maintenance	$0	0.0%	$0.0000
Total Savings	$919,075	100.0%	$0.0390
COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($39,445)	4.7%	($0.0017)
Compressor	($36,919)	4.4%	($0.0016)
Storage Vessels	($91,857)	10.9%	($0.0039)
Dispenser	($24,857)	2.9%	($0.0011)
Dryer	($9,943)	1.2%	($0.0004)
Subtotal	($203,021)	24.0%	($0.0086)
Vehicle			
Conversion Kit	($105,290)	12.5%	($0.0045)
Tanks	($125,720)	14.9%	($0.0053)
Labor	($125,720)	14.9%	($0.0053)
OEM	$0	0.0%	$0.0000
Subtotal	($356,731)	42.3%	($0.0151)
Operating			
Station Maint.	($55,603)	6.6%	($0.0024)
Cylinder Recert.	($3,171)	0.4%	($0.0001)
Power	($75,035)	8.9%	($0.0032)
Labor - fuel time loss	($122,414)	14.5%	($0.0052)
NG Fuel Tax	($28,281)	3.3%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($284,504)	33.7%	($0.0121)
Total Costs	($844,255)	100.0%	($0.0358)
Savings - Cost	$74,820	N/A	$0.0032

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	100,000	$3,000	N/A

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

STATION DESIGN	
Year 1: Compressor Size (scfm)	32
Year 1: Storage Size (scf)	87,294

Annual Maintenance Savings	0%

ASSUMPTIONS
1. Fueling station is designed for continuous fast-filling.
2. OEM's are not availble during the 30 year period.
3. Automobiles are sold off at the end of the year when they reach the following number of miles:
200,000

Benefit/vehicle/year	$317.47
Incremental Benefit/mile	$0.0032

Fleet Size
Large (50)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$1,646,183	91.3%	$0.0349
Vehicle Tax Deduction	$121,966	6.8%	$0.0026
Station Tax Deduction	$35,000	1.9%	$0.0007
Maintenance	$0	0.0%	$0.0000
Total Savings	$1,803,149	100.0%	$0.0383
COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($52,727)	3.4%	($0.0011)
Compressor	($55,426)	3.6%	($0.0012)
Storage Vessels	($124,856)	8.1%	($0.0026)
Dispenser	($24,857)	1.6%	($0.0005)
Dryer	($9,943)	0.6%	($0.0002)
Subtotal	($267,809)	17.4%	($0.0057)
Vehicle			
Conversion Kit	($210,580)	13.7%	($0.0045)
Tanks	($251,441)	16.3%	($0.0053)
Labor	($251,441)	16.3%	($0.0053)
OEM	$0	0.0%	$0.0000
Subtotal	($713,461)	46.3%	($0.0151)
Operating			
Station Maint.	($111,205)	7.2%	($0.0024)
Cylinder Recert.	($6,343)	0.4%	($0.0001)
Power	($140,216)	9.1%	($0.0030)
Labor - fuel time loss	($244,828)	15.9%	($0.0052)
NG Fuel Tax	($56,561)	3.7%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($559,154)	36.3%	($0.0119)
Total Costs	($1,540,424)	100.0%	($0.0327)
Savings - Cost	$262,725	N/A	$0.0056

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	100,000	$3,000	N/A

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	64
Year 1: Storage Size (scf)	118,493

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM's are not availble during the 30 year period.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$557.39
Incremental Benefit/mile	$0.0056

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APPENDIX H

NPV TAXI COST-EFFECTIVENESS MODEL
REDUCED OEM PRICE

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$175,964	80.5%	$0.0373
Vehicle Tax Deduction	$9,567	4.4%	$0.0020
Station Tax Deduction	$32,943	15.1%	$0.0070
Maintenance	$0	0.0%	$0.0000
Total Savings	$218,474	100.0%	$0.0464
COSTS		**% of Costs**	**Incremental Cost/Mile**
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($17,823)	9.4%	($0.0038)
Compressor	($22,108)	11.7%	($0.0047)
Storage Vessels	($22,739)	12.0%	($0.0048)
Dispenser	($24,857)	13.2%	($0.0053)
Dryer	($9,943)	5.3%	($0.0021)
Subtotal	($97,469)	51.6%	($0.0207)
Vehicle			
Conversion Kit	($4,379)	2.3%	($0.0009)
Tanks	($5,000)	2.6%	($0.0011)
Labor	($8,757)	4.6%	($0.0019)
OEM	($16,951)	9.0%	($0.0036)
Subtotal	($35,087)	18.6%	($0.0074)
Operating			
Station Maint.	($9,863)	5.2%	($0.0021)
Cylinder Recert.	($171)	0.1%	$0.0000
Power	($20,634)	10.9%	($0.0044)
Labor - fuel time loss	($20,037)	10.6%	($0.0043)
NG Fuel Tax	($5,656)	3.0%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($56,361)	29.8%	($0.0120)
Total Costs	($188,917)	100.0%	($0.0401)
Savings - Cost	$29,557	N/A	$0.0063

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	100,000	$3,000	$1,200

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	6
Year 1: Storage Size (scf)	21,946

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$627.08

Incremental Benefit/mile	$0.0063

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Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$879,821	91.4%	$0.0373
Vehicle Tax Deduction	$47,835	5.0%	$0.0020
Station Tax Deduction	$35,000	3.6%	$0.0015
Maintenance	$0	0.0%	$0.0000
Total Savings	$962,656	100.0%	$0.0408

COSTS		% of Costs	Incremental Cost/Mile
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($39,297)	6.3%	($0.0017)
Compressor	($36,349)	5.8%	($0.0015)
Storage Vessels	($91,857)	14.7%	($0.0039)
Dispenser	($24,857)	4.0%	($0.0011)
Dryer	($9,943)	1.6%	($0.0004)
Subtotal	($202,302)	32.5%	($0.0086)
Vehicle			
Conversion Kit	($21,895)	3.5%	($0.0009)
Tanks	($25,000)	4.0%	($0.0011)
Labor	($43,783)	7.0%	($0.0019)
OEM	($84,756)	13.6%	($0.0036)
Subtotal	($175,434)	28.1%	($0.0074)
Operating			
Station Maint.	($49,316)	7.9%	($0.0021)
Cylinder Recert.	($854)	0.1%	$0.0000
Power	($66,884)	10.7%	($0.0028)
Labor - fuel time loss	($100,187)	16.1%	($0.0043)
NG Fuel Tax	($28,281)	4.5%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($245,521)	39.4%	($0.0104)
Total Costs	($623,257)	100.0%	($0.0264)
Savings - Cost	$339,399	N/A	$0.0144

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	100,000	$3,000	$1,200

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	32
Year 1: Storage Size (scf)	87,294

ASSUMPTIONS
1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$1,440.13
Incremental Benefit/mile	$0.0144

Fleet Size
Large (50)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$1,759,642	93.1%	$0.0373
Vehicle Tax Deduction	$95,670	5.1%	$0.0020
Station Tax Deduction	$35,000	1.9%	$0.0007
Maintenance	$0	0.0%	$0.0000
Total Savings	$1,890,312	100.0%	$0.0401
COSTS		**% of Costs**	**Incremental Cost/Mile**
Infrastructure			
Land	$0	0.0%	$0.0000
Station setup	($52,429)	4.8%	($0.0011)
Compressor	($54,281)	4.9%	($0.0012)
Storage Vessels	($124,856)	11.4%	($0.0026)
Dispenser	($24,857)	2.3%	($0.0005)
Dryer	($9,943)	0.9%	($0.0002)
Subtotal	($266,366)	24.2%	($0.0057)
Vehicle			
Conversion Kit	($43,791)	4.0%	($0.0009)
Tanks	($50,000)	4.5%	($0.0011)
Labor	($87,566)	8.0%	($0.0019)
OEM	($169,511)	15.4%	($0.0036)
Subtotal	($350,868)	31.9%	($0.0074)
Operating			
Station Maint.	($98,633)	9.0%	($0.0021)
Cylinder Recert.	($1,708)	0.2%	$0.0000
Power	($124,696)	11.3%	($0.0026)
Labor - fuel time loss	($200,374)	18.2%	($0.0043)
NG Fuel Tax	($56,561)	5.1%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($481,971)	43.8%	($0.0102)
Total Costs	($1,099,205)	100.0%	($0.0233)
Savings - Cost	$791,107	N/A	$0.0168

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	100,000	$3,000	$1,200

FUEL PRICES	
Natural Gas Price/mcf	$3.09
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.38

DISCOUNT RATE	10.0%

OTHER FACTORS	
Electricity Cost ($/kWh)	$0.063
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

STATION DESIGN	
Year 1: Compressor Size (scfm)	64
Year 1: Storage Size (scf)	118,493

ASSUMPTIONS

1. Fueling station is designed for continuous fast-filling.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles:
200,000

Benefit/vehicle/year	$1,678.40
Incremental Benefit/mile	$0.0168

APPENDIX I

NPV TAXI COST-EFFECTIVENESS MODEL
PUBLIC REFUELING

Fleet Size
Small (5)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$103,338	91.5%	$0.0219
Vehicle Tax Deduction	$9,567	8.5%	$0.0020
Maintenance	$0	0.0%	$0.0000
Total Savings	$112,905	100.0%	$0.0240

COSTS		% of Costs	Incremental Cost/Mile
Vehicle			
Conversion Kit	($4,379)	5.3%	($0.0009)
Tanks	($5,000)	6.1%	($0.0011)
Labor	($8,757)	10.6%	($0.0019)
OEM	($38,255)	46.5%	($0.0081)
Subtotal	($56,391)	68.6%	($0.0120)
Operating			
Cylinder Recert.	($171)	0.2%	$0.0000
Labor - fuel time loss	($20,037)	24.4%	($0.0043)
NG Fuel Tax	($5,656)	6.9%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($25,864)	31.4%	($0.0055)
Total Costs	($82,255)	100.0%	($0.0175)
Savings - Cost	$30,650	N/A	$0.0065

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	5	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$5.79
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.71

DISCOUNT RATE	10.0%

OTHER FACTORS	
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

ASSUMPTIONS
1. Fueling is done at a public-fueling station.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$650.26

Incremental Benefit/mile	$0.0065

Fleet Size
Medium (25)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$516,688	91.5%	$0.0219
Vehicle Tax Deduction	$47,835	8.5%	$0.0020
Maintenance	$0	0.0%	$0.0000
Total Savings	$564,523	100.0%	$0.0240
COSTS		**% of Costs**	**Incremental Cost/Mile**
Vehicle			
Conversion Kit	($21,895)	5.3%	($0.0009)
Tanks	($25,000)	6.1%	($0.0011)
Labor	($43,783)	10.6%	($0.0019)
OEM	($191,274)	46.5%	($0.0081)
Subtotal	($281,953)	68.6%	($0.0120)
Operating			
Cylinder Recert.	($854)	0.2%	$0.0000
Labor - fuel time loss	($100,187)	24.4%	($0.0043)
NG Fuel Tax	($28,281)	6.9%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($129,321)	31.4%	($0.0055)
Total Costs	($411,274)	100.0%	($0.0175)
Savings - Cost	$153,249	N/A	$0.0065

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	25	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$5.79
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.71

DISCOUNT RATE	10.0%

OTHER FACTORS	
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

ASSUMPTIONS
1. Fueling is done at a public-fueling station.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$650.26

Incremental Benefit/mile	$0.0065

Fleet Size
Large (50)

SAVINGS	30 year NPV	% of Savings	Incremental Savings/Mile
Gasoline Price Diff.	$1,033,376	91.5%	$0.0219
Vehicle Tax Deduction	$95,670	8.5%	$0.0020
Maintenance	$0	0.0%	$0.0000
Total Savings	$1,129,045	100.0%	$0.0240
COSTS		**% of Costs**	**Incremental Cost/Mile**
Vehicle			
Conversion Kit	($43,791)	5.3%	($0.0009)
Tanks	($50,000)	6.1%	($0.0011)
Labor	($87,566)	10.6%	($0.0019)
OEM	($382,549)	46.5%	($0.0081)
Subtotal	($563,905)	68.6%	($0.0120)
Operating			
Cylinder Recert.	($1,708)	0.2%	$0.0000
Labor - fuel time loss	($200,374)	24.4%	($0.0043)
NG Fuel Tax	($56,561)	6.9%	($0.0012)
Additional training	$0	0.0%	$0.0000
Subtotal	($258,643)	31.4%	($0.0055)
Total Costs	($822,548)	100.0%	($0.0175)
Savings - Cost	$306,497	N/A	$0.0065

VEHICLE DATA	# Vehicles	Gasoline MPG	Annual Miles per vehicle	CNG Conversion Cost per vehicle	OEM Cost Differential per vehicle
Automobiles	50	20.0	100,000	$3,000	$2,500

FUEL PRICES	
Natural Gas Price/mcf	$5.79
Gasoline Price/gallon	$1.10
Natural Gas Price per Gallon of gasoline equivalent	$0.71

DISCOUNT RATE	10.0%

OTHER FACTORS	
Labor Cost ($/hr)	$10.00

Annual Maintenance Savings	0%

ASSUMPTIONS

1. Fueling is done at a public-fueling station.
2. OEM vehicles are available at the beginning of year 1998.
3. Automobiles are sold off at the end of the year when they reach the following number of miles: 200,000

Benefit/vehicle/year	$650.26

Incremental Benefit/mile	$0.0065