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Final Report

Compressed Natural Gas as a Transportation Fuel in Cairo

A Feasibility Study

November 1994

Prepared For

U.S. Agency for International Development
Cairo Mission

Prepared By

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Submitted By:

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DISCLAIMER

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List of Abbreviations

A.I.D.-	U.S. Agency for International Development
ASME -	American Society of Mechanical Engineers
ASNT -	American Society of Nondestructive Testing
AWS -	American Welding Society
BHP -	Brake horsepower
BTU -	British Thermal Units
CF -	Cubic feet
CI -	Compression ignition
CNG -	Cmpressed Natural Gas
CO -	Carbon Monoxide
CO2 -	Carbon Dioxide
CTA -	Cairo Transit Authority
DDC -	Detroit Diesel Corporation
dl -	Deciliters
DOT -	Department of Transportation
EAP -	Environmental Action Plan
EEAA -	Egyptian Environmental Affairs Agency
EPA -	U.S. Environmental Protection Agency
GCBC -	Greater Cairo Bus Company
HC -	Hydrocarbon
ISA -	Instrument Society of America
km -	Kilometers
kWh -	Kilowatt hour
L.E. -	Pounds Egyptian, currency
m^3 -	Cubic meters
NEMA -	National Electrical Manufacturers Association
NFPA -	National Fire Protection Association
NGV -	Natural gas vehicle
NIST -	National Institute of Standards and Technology Handbook 44
NMHC -	Non-methane hydrocarbon
NOx -	Nitrogen oxides
NPV -	Net Present Value
OECP -	Organization for Energy Conservation and Planning
OSHA -	Occupational Safety and Health Act and Title 8, Article 7 of the Administrative Division of Industrial Safety, General Safety Orders
PING -	Detroit Diesel Corporation acronym for their Dual fuel, closed loop controlled engines
PM10 -	Particulate matter less than 10 microns
ppm -	Parts per million
SCFM -	Standard cubic feet per minute
SI -	Spark ignition
SO2 -	Sulphur dioxide
TSP -	Total Suspended particulate

ug -	Microgram
UBC -	Uniform Building Code
UFC -	Uniform Fire Code
UL -	Underwriters Laboratory Approval
UNDP -	United Nations Development Program
UNEP -	United Nations Environment Program
WHO -	World Health Organization

Section 1.0 Executive Summary

This report presents the results of an analysis of the feasibility of using compressed natural gas (CNG) in vehicles in Cairo. The purpose of the study is to help identify portions of the Cairo vehicle population that could be converted economically to operate on CNG, to describe requirements, and to assess economic and environmental benefits. Technical, financial, economic, environmental, institutional, and policy considerations have been included in the analyses. No project design related activities have been performed by the Datex study team.

The study team concluded that, in general, the use of new, dedicated CNG engines was the most technically certain and economically attractive approach for the bus fleet and the truck fleet. For passenger cars and light trucks, bi-fuel operation offers the best financial return compared to dedicated CNG approaches. **The conversions are considered technically feasible,** if associated with comprehensive engineering and pilot phases, thorough training, and the establishment of necessary institutional capacities, including development of safety standards, regulations, certification procedures, and inspections.

Economic Analyses

Analyses indicate that use of **CNG in the Cairo Transport Authority (CTA) bus fleet is attractive economically.** A number of sensitivity analyses confirm that conversion of this bus fleet would be economically viable even if actual conditions were significantly different than assumed in the base case. Internal rate of return on an investment of approximately L.E.128 million was estimated to be about 45 percent for the base case, and in the range of 23 to 90 percent for all conditions evaluated in the sensitivity analyses. Simple payback periods were found to be in the three to five year range for most conditions. Installation of new, dedicated CNG engines was shown to be most attractive, but dual fuel (both open loop and closed loop controlled) and bi-fuel retrofits would also be positive investments.

Analyses of **CNG conversion of a fleet of heavy duty delivery trucks for the Cairo Beverage and Industrial Company indicate marginal economic returns:** less than the 10 percent discount rate assumed. However, sensitivity analyses show that, under some conditions, conversions can be economically viable. For instance, a fleet-owned refueling station cannot be justified for the delivery truck fleet. However, if the truck fleet could use an existing fueling station, then the rate of return is estimated to be over 40 percent.

Conversion of **fleets of passenger cars and light duty (pickup) trucks** were evaluated based on assumptions of some typical conditions. It was shown that these vehicle conversions cannot **generally be justified economically** because of their relatively low usage rates, high fuel economy, diversity of engine type, and cost of conversion. However, the economic evaluation results were not strongly negative even for these vehicles, indicating that incentives could be developed to encourage conversion of a portion of them, especially in fleet applications.

Several potential types of vehicles that may offer opportunities for economically attractive CNG

conversions, including taxis and microbuses, were not evaluated because of the lack of data characterizing their operation. It can be expected that their higher daily usage rate would cause them to be better candidates than typical passenger cars.

Policy Issues

The economic analysis indicated that import/export balance benefits, environmental benefits, and the financial savings of its citizens combine to make CNG use in vehicles attractive to Egyptian society as a whole. In that light, the Government of Egypt can take several steps to provide additional incentives to encourage CNG vehicle conversions. The first involves the CNG refueling infrastructure, which always represents a significant portion of the total investment in a conversion program. Vehicle owners will not convert to CNG unless they feel confident in the convenient availability of the fuel. The Government could encourage CNG conversion by operating or facilitating third party ownership of refueling stations.

Most of the economic analyses in this study were performed assuming that the fleet owner would also be the refueling station owner and rates of return were based on the total cost for vehicles and stations. However, the refueling station could be owned and operated by a third party who could make a profit on the sale of the gas to give them an equivalent rate of return. The stations' selling price of natural gas must be carefully calculated to ensure a balance of financial return for both the station owners and the vehicle owners.

The GOE could provide incentives for CNG vehicle conversions through several other mechanisms: by reducing the cost of natural gas to the transportation sector; placing extra taxes on certain new, non-CNG vehicles (such as buses); reducing import taxes on CNG components and vehicles; providing high pressure gas distribution lines directly to refueling station locations; or providing land for refueling stations. To be effective, some of these measures would require that any resulting capital cost savings by the station owner be passed through to the vehicle owners in the form of reduced natural gas prices charged.

Environmental Analysis

The environmental analysis performed for the CTA bus fleet case indicates that environmental cost benefits are equivalent to a range of approximately 10 to 20 percent of the total fuel cost savings, depending on the specific options chosen. The greatest concentration reduction benefits to be realized in any CNG conversion program beyond simple dual-fuel retrofit of diesel buses are in PM_{10} and sulfur oxides, with the potential for modest carbon monoxide reduction a minor secondary benefit. Based on a significant number of assumptions made in the absence of confirming research, the team estimated conservatively that conversion of the CTA bus fleet to natural gas could eliminate between one and ten latent cancer fatalities out of every 10,000 per year among *longtime* Cairo inhabitants. Other environmental benefits are also discussed in the report.

Institutional Analysis

A review of institutional requirements was conducted. An initial estimate is that the implementation of CNG operations in the public bus fleet only, not to expand CNG use elsewhere, will involve approximately 50 new personnel positions across all participating Egyptian organizations. Training requirements were also estimated and provided in the report.

Institutional requirements associated with the following types of activities were identified:

- Program Planning, Coordination and Evaluation
- Coordination with Transportation Requirements
- Coordination with Natural Gas Supply System
- Physical Connection to the Natural Gas Supply System
- Establishment of Safety Standards
- Establishment of Safety Regulations, Licensing and Certification Procedures
- Initial and Periodic Inspection of Vehicles
- Initial and Periodic Inspection of Stations
- Conduct of Air Quality and Transportation Research
- Conduct of Emissions Testing
- Development of a Public Awareness/Information Campaign
- Publishing Program Reports
- Implementation of a Broad Training Program
- Evaluation of Acceptance by Participants
- Conduct of CNG Vehicle Feasibility Studies for Other Fleets
- Coordination and Support of Industries for Local Manufacture of CNG System Components
- Physical Conversion of Vehicles
- Operation of Filling Stations
- CNG Fleet Operation

Economic Analysis Methods

Economic analyses were performed using a flexible model developed specifically for this project on a Macintosh version of EXCEL spreadsheet software. In addition to the rate of return the model reports benefit/cost ratio, a summary of cash flow from which payback can be determined, and net present value. The model calculates dollar equivalents for environmental benefits of pollution reduction for each scenario. The model also predicts total impact on the country's import/export balance. The analysis for the CTA bus fleet was conducted on an individual bus garage basis. Results for the whole fleet were extrapolated from that data.

Recommendations

The CTA bus fleet should be converted to CNG operation. Any conversion program should be carefully designed and should include a comprehensive engineering phase, as well as a thorough pilot phase to ensure successful operation. A comprehensive training program is needed as well.

The following approach is recommended.

a. New Buses: Each year the CTA purchases approximately 100 to 200 new buses depending on the available budget. These buses should be dedicated CNG vehicles. This may require the purchase of new dedicated CNG engines by a public sector company such as NASCO or a CTA garage shop or a private sector company to install in the new buses, and some slight re-engineering of the buses. Some relatively inexpensive CNG engines are available in the American market, such that the incremental cost for a CNG bus should be small.

b. New engines: Each year the CTA purchases approximately 300 to 500 new engines for their bus fleet. These engines should be new dedicated CNG engines. Some slight re-engineering of the buses may be necessary to mount the new engines. These engines could be either specially engineered for CNG and assembled in Egypt or U.S. CNG engines.

c. Overhauls: Currently, after a new diesel engine has been in service five years, it is overhauled every year. This overhaul costs L.E.20,000. Purchase of new, dedicated CNG engines instead of overhauling old diesels appears economical. If need for an overhaul in a bus can be eliminated for two years by using the new CNG engine, L.E.40,000 can be saved, which would cover the majority of the new engine costs.

d. Refueling stations: Using the approaches listed in a, b, and c above, the introduction of CNG can occur at a fast pace. Thus, the time before the fueling stations would be heavily used would be short. Also, if the refueling stations can be configured and made accessible to other vehicles or fleets for daytime filling, the investment made in the stations can be reduced and more fleets, including bus, truck, and light duty vehicles, can be economically converted.

e. Pilot program: As part of the CNG bus conversion program, the Ministry of Petroleum, Egypt Gas, the Egyptian CNG Committee, CTA, GCBC, EEAA, and USAID should include an operational pilot program preferably at one garage located close to a 30 bar natural gas line. If the gas in the high pressure line comes from the Abu Maadi and/or Abu Quir gas fields, then the cost of the compressors and fuel cost of compression will be less and the quality of the gas would meet the most stringent specifications for natural gas engines.

There is evidence that dual fuel conversion of existing diesel buses is not attractive from the standpoints of fuel economy, field operation of the engines, and emissions when compared to dedicated natural gas engines. It might be worthwhile, therefore, to test, select and install appropriate conversion kits to operate some diesel engines manufactured in Egypt as dedicated retrofit engines.

The pilot project should be planned and implemented as a regular revenue

earning project to maximize the value of engineering, economic and emission data can be generated.

Next Steps

Based on the results of this study, the following actions are recommended as reasonable next steps:

- The Ministry of Petroleum has recognized that Egypt should develop a national strategy for conversion of portions of the transportation sector to CNG. This strategy may focus initially on Cairo, but may appropriately include eventual expansion of the CNG fueling station infrastructure beyond Cairo.

- The design of the initial fleet conversion program should be begun.

- A detailed analysis of the long term natural gas pricing structure as applied to the transportation sector should be performed. The success of the CNG conversion program hinges on the long term stability, or at least predictability, of fuel prices.

- A major effort for the development of safety standards and an equipment certification program should begin early to ensure that unsafe equipment or procedures are not used. Failure or accidents early in the program due to improper equipment or procedures could seriously jeopardize acceptance of the program.

- An emissions testing facility should be established quickly to provide information for refinement of the program design, for program evaluation, for establishment of standards, and for emissions certification tests.

- The economic analysis model developed for this study should be documented and refined to maximize its value for analysis of other Egyptian fleet conversions and to support development of the national strategy and initial program design.

- A study should be performed to refine the environmental cost component of the economic model. The analysis was based on recently developed values for the cost of emissions of various pollutants in the U.S. These values were then decreased for application to Egypt based on the ratio of Egyptian GDP to U.S. GDP. This simple proportioning of costs may underestimate benefits to Egypt.

- Several types of vehicles and fleets that could be potentially viable CNG conversion opportunities were not evaluated because adequate data were not available within the time limitations of this study. Study of additional fleets should continue. Examples of several candidates for early investigation are the Greater Cairo Bus Company public transit fleet, the bus fleets of the large industrial companies, and the microbus fleet.

- Liquified Natural Gas (LNG) vehicle technology is very similar to CNG technology. LNG offers the advantage of significantly reduced in-vehicle storage weight and space. An investigation of LNG use was not within the scope of this study, but may be worthwhile as part of a long term strategy.

Section 2.0 Introduction

2.1 Purpose and Scope

This report presents the results of an analysis of the feasibility of using compressed natural gas (CNG) in vehicles in Cairo. The purpose of the study is to help identify portions of the Cairo vehicle population that could economically be converted to operate on CNG, to describe requirements, and to assess economic and environmental benefits. The Egyptian Government is interested in the potential application of this technology and USAID is considering CNG use in vehicles as a component of a program to address the poor air quality in Cairo. Other donor agencies have also expressed interest in the technology for use in Cairo. Accurate information is needed to determine appropriate future steps for adopting CNG vehicle technology on a broad scale. Obviously, much additional analyses and planning must be performed to begin implementing a program. This study is a first effort to determine where to begin and to scope the magnitude of the benefits.

Technical, financial, economic, environmental, institutional, and policy considerations have been included in the analyses. No project design related activities have been performed.

This study is based on the assumption that adequate natural gas is available to apply to the transportation sector so that natural gas supply is not a limiting factor. A brief summary of the natural gas resources and a discussion of natural gas pricing and the impact of supply is provided.

No alternative methods for improving air quality in Cairo are discussed at length. There are many sources of pollution that affect the quality of ambient air in Cairo. Different types of economic activity in and around Cairo are contributors to the poor air quality. The major polluters within the Governorate of Cairo, Kalyoubia and Giza are the following: industries and the power plants in Shubra El Khema; the cement factories and other heavy industries in Helwan; lead smelters and the lead in the regular gasoline; occasional dust storms; the burning of garbage within city limits; and emissions from trucks, buses, passenger cars, and motorcycles. One must remember that the transportation sector is only one source of air pollution in the city. Within the transportation sector, alternative fuels are one of many potential approaches to reduce emissions. Similarly, compressed natural gas is one of several alternative fuels being investigated and used in various places around the world. The scope of work for this analysis does not include a comparison of the effectiveness of CNG use in vehicles versus other air quality measures.

The report is not focused on strategy for expanding the CNG vehicle fleet, although some recommendations based on the findings are made. By strategy, we mean the prioritization and sequencing of steps that Egypt should take to implement a broad program of CNG use in vehicles or where initial capital should be spent. For selected portions of the total vehicle population, the report describes requirements and feasibility. Some measures and policies that could help encourage the widespread adoption of CNG are identified.

The phrase "CNG conversion" at the program level may at times be confusing. Throughout this report, the phrase is taken to mean adoption of CNG use in vehicles, whether by "converting" or retrofitting existing vehicles with modified engines or engines built originally to use CNG, or by purchasing new vehicles built to use CNG. The reader is urged to take careful note of the specific approaches being discussed at various points within this document.

2.2 Background

Four factors have led to an interest in adopting CNG vehicle technology in Egypt.

First, annual additions of proved reserves of natural gas in Egypt have spiked upward since 1992, increasing by more than 50 percent in that time frame [(The Economist Intelligence Unit, 1994; Abdel-Hakim, Feb. 1993; Tawila, Oct. 1993). (See list of publications in the Appendix.)] This upward spike in gas reserves followed a several year expansion of proved gas reserves from 1985 to 1990 amounting to a 75 percent cumulative increase. Gas consumption did not keep up with the expansion in reserves, increasing by only 66 percent during the same time interval. The recorded expansion of proved reserves since 1992 has been great but less than the doubling anticipated (Tawila, Oct. 1993, p. 11). Proved oil reserves, in contrast, have remained relatively stable since 1975, while oil consumption increased by 144 percent from 1975-85, and a total of only 11 percent from 1985-91 (Abdel-Hakim, Feb. 1993). The demonstrated and anticipated increases in natural gas reserves led to a desire to assess the development of potential new markets for natural gas, transportation being "on the top of a list of new applications" (Tawila, Oct. 1993, p. 22).

Second, Egypt has agreed to remove subsidies of petroleum products and bring the weighted average of Egyptian petroleum product prices up to 100 percent of world prices by June 1995, and to set bulk natural gas prices at an international fuel oil equivalent price by the same date (World Bank, June 1991). Egypt had already recognized that the long-term rates of expansion of the demand for petroleum products would not be sustainable without a need to import crude oil in the future. The price of gasoline was increased to levels higher than world prices in the second half of the 1980s, and annual price increases near ten percent were cut to less than one percent for the 1985-91 period.

However, gasoil prices - the prices paid by diesel fueled commercial vehicles and public transport buses - continued to be subsidized through the early 1990s, and growth in demand for this product continued to exceed the overall demand for petroleum products. Other heavy products (diesel and fuel oil) also continued to be subsidized. Prices faced by consumers of gasoil, diesel, and fuel oil will rise sharply by June 1995, and are already increasing rapidly. Accordingly, owners of vehicles making use of gasoil as a fuel will inevitably be doing careful reevaluation of their vehicle technology and fuel choices in the next year or so, examining the merits of either greater fuel efficiency, fuel switching (to gasoline or natural gas), or both.

A third factor leading to an interest in CNG vehicles in Cairo is a shift of emphasis within the U.S. Agency for International Development. Greater emphasis is now placed on environmental issues in the criteria used for selecting developmental projects in nations receiving aid. This is

a relatively recent development coinciding chronologically with the expansion of Egypt's natural gas reserves. Considerable world-wide research has been conducted to determine the pollution from engine emissions using different fuels. This research was used to establish national pollution standards for auto emissions in various countries. Natural gas has been identified as one of the less polluting alternative fuels.

Finally, **the fourth factor** is an increasing worldwide effort toward consideration of natural gas as an economically viable and environmentally friendly transportation fuel. The phenomenon in Egypt - greater addition of gas reserves to the hydrocarbon reserve base than of crude oil - is a worldwide phenomenon. Attempts to find oil in geologically promising areas are frequently leading to discoveries of gas instead. This is resulting in a relative excess of natural gas worldwide. In locations where the natural gas discoveries are close to major urban areas, natural gas is often economically competitive with crude oil, and is given careful attention as a substitute for oil. Examples are the north island of New Zealand, the province of British Columbia in Canada, the Po Valley area of Italy, Perth in western Australia, and Santiago, Chile. In addition, nations concerned over the long-term availability of petroleum also have adopted pro-natural gas policies promoting the use of natural gas even when it is not currently economically justified on the basis of tax equivalent pricing. Most of the U.S. and eastern provinces of Canada fall in this category. An important consideration furthering the development of natural gas vehicles in eastern Canada and the U.S. is a concern over the emissions of gasoline and diesel fueled vehicles. Natural gas industries, research institutions, and government bodies have all contributed to the development of natural gas technologies which are considerably cleaner than current vehicles fueled by petroleum products. Thus, natural gas engine and fuel system technology and vehicle design experience are available for Egypt to use for development of appropriate natural gas vehicles.

2.3 Approach

The overall duration of this feasibility study was approximately six months. The effort began with a data gathering phase of several weeks duration beginning in late April, 1994. A team of five individuals visited Cairo at various times during different portions of the data gathering phase, each individual staying from two to five weeks. Numerous personnel in Egyptian organizations and USAID were interviewed and sites visited. A list of persons interviewed is provided in an Appendix. Several members of the team returned to Cairo in late July 1994 to write the draft report. Comments were received from a number of reviewers and most comments are reflected in the final report.

A specialized economic model was developed to permit rapid evaluation of the internal rate of return and other economic and financial parameters. Evaluation of all portions of the Cairo vehicle population is not possible in this type of study, so a strategy was chosen in which data were gathered on the total vehicle population and those data were screened to identify those portions for which CNG conversions were most likely to be feasible. For instance, most CNG conversion programs around the world have focused on conversions of specific vehicle "fleets." Cairo has been found to have a limited number of true fleets operations, with central ownership and maintenance that return to a central base each day. The public bus fleets are one example

of a true fleet operation in Cairo. Similarly, some companies have relatively large fleets of delivery trucks that have standard delivery runs and operate from a central facility. Some large industries have fleets of buses for their employees. This is not to say that only vehicles operating under this strict definition of a "true fleet" are candidates for operation on CNG. However, it is not within the scope of this effort to evaluate every company's fleet. Thus, the approach taken was to perform detailed evaluations of a selected set of applications and include sensitivity analyses for significant parameters to permit the reader to draw conclusions for a much broader range of applications.

2.4 Report Organization

A brief summary of CNG vehicle technology, Section 3, follows this Introduction. In Section 4, we provide data describing the general vehicle population in Cairo and the vehicular fuels situation, focusing on the natural gas supply. In the Statement of Work and during our discussions in Egypt, several topics were identified as requiring special attention and are discussed in subsequent sections. In Section 5, we summarize information on several of these topics, such as "safety," which of necessity are also touched upon throughout the report. In Section 6, we describe the vehicles that were selected for detailed study. More than ten specific "options" have been selected for detailed analysis. These selected options are evaluated in the economic analysis of Section 7. Many conclusions are discussed there, many additional nuances and interesting relationships resulting from the outputs are apparent through review of the tabular output summaries. The range of environmental consequences likely to result from conversion to CNG is discussed in Section 8. The environmental benefits resulting from conversion of the public bus fleet are discussed to provide a perspective on the magnitude of effects likely to result.

The Institutional Requirements evaluation presented in Section 9 discusses the functions and activities necessary to support a CNG conversion program. Estimates of manpower and training required are included. Finally, Section 10 summarizes the conclusions and recommendations of the study team based on the data gathered and analyses performed. The Appendices contain much useful information to support the various sections of the report and document data gathered.

Section 3.0 Summary of CNG Vehicle Technology Status

3.1 Experience with CNG Fleet Vehicles

The use of natural gas as an alternative fuel to diesel and gasoline began in the 1930s. Today, there are about 700,000 natural gas vehicles world-wide. There are approximately 235,000 in Italy, 200,000 in the Newly Independent States (the former Russia), 100,000 in Argentina, 30,000 in the United States, and 26,000 in Canada.

3.1.1 Experience Worldwide

In reviewing previous experience, one must distinguish between "**Demonstration Projects**" and fleet vehicle operations set up as "**Revenue Operation Projects**". Demonstration projects are planned to test and prove specific issues. Under revenue operation projects, the vehicles are put into actual service on established routes and are designed to generate income from passenger fares and incur actual field and maintenance costs from the service. Since other (diesel) buses will be operating the same routes, this approach offers a better comparison of two types of fleet vehicles operated over a long period of time.

3.1.1.1 80 Diesel Bus Fleet Partially Converted to CNG for Town Service in Ravenna, Italy

This conversion project was implemented purely for environmental reasons. A three year environmental protection study of the city revealed atmospheric and noise pollution as the principal areas of concern. A Ministerial Decree approved the operation of CNG vehicles in Ravenna. The project was designed to reduce the noise and air pollution levels and to demonstrate cost savings. The following table provides the data on operating the buses that had travelled an average annual distance of 35,000 Km. An energy equivalence of one m^3 of natural gas for one Liter of diesel fuel was used for the analyses.

3.1.1.2 City & Regional Transit Systems In Netherlands

The Central Netherlands Gas company converted eleven diesel buses to operate on CNG. During the second stage of the project, an additional seven CNG buses were put in service, five in one city and one each in two other cities. The buses were fitted with 11 eighty liter cylinders giving a range 384 km for the regional bus and 315 km for the city bus. The conversion to CNG increased the vehicle weight by 1200 kg. The fuel consumption increased by 24 percent partly because of the increase in the weight of the bus.

The torque of the converted bus was lower than the original diesel vehicle because the engines were tuned for low NO_x emissions. The project reported the following problems after the vehicles had accumulated 380,000 km and 340,000 km respectively on the regional and city routes:

- Twenty incidents of backfiring resulting from lean mixtures or from ignition defects;
- Thirty incidents of malfunction in the Gas controlled system causing changes in idle speed; and
- On fifty occasions the electromagnetic valves malfunctioned which were caused by NG condensates and/or compressor oil in the system.

Exhibit 3.2 compares the emissions from the diesel and CNG vehicles operating the regional and city routes.

Exhibit 3.1 Fuel Cost Comparison Between an all CNG and a Diesel Bus in the Ravenna 80 Bus Fleet
(Source: Montanari R. 1992)

	CNG (lire/m³)	Diesel (lire/lt)
Price at Pump	420	1,112
Price before tax	153 (1)	430
Consumption/manufacturing tax	---	504
VAT 19%	29	178
VAT recoupment (2)	-4	-27
Total Tax	25	655
Compression	20	---
Fuel station investment (3)	50	---
Total	70	---
Grand Total	248	1,085
Cost per kilometre (lit/km) (4)	124	543
Annual cost (lire) (5)	4,340,000	19,005,000

(1) Arithmetic average of current rate time bracket 1
(2) Calculation based on VAT recoupment of 15%
(3) Cost estimated on the basis of an investment of 600 million lire with 20 year depreciation at 10% (70 million lire/year), serving a fleet of 80 buses
(4) Experience justifiesan efficiency per kilometre equivalence of one cu.m. of CNG to one litre of diesel fuel
(5) For a mean annual mileage of 35,000 km account has not been taken either of the incidence of the diesel fuel station investment or of minor maintenance costs in CNG operation

Exhibit 3.2 Comparison of Diesel Emissions with Regional and City Buses Operating on CNG
(Van Der Weide J., 1992)

Standard/Test	NO_x	HC	CO	Particulate
Diesel bus	14.0	2.4	11.1	---
Regional bus CNG	2.9	3.1	0.25	<0.05
City bus CNG	4.3	2.1	0.4	<0.05

3.1.1.3 Yellow Bus Company (YBC) Operations in New Zealand

Since 1987 a total of 80 buses were converted to run on CNG and to date, the total distance travelled by the first bus put in service is over 300,000 km. The limitation in the range of operation was quoted as a major disadvantage with the CNG vehicles. Oil monitoring indicated a decrease of about 20 percent in wear metals and as the distance travelled exceeded 300,000 km, this reduction translated into similar decreases in wear. Spark plugs were replaced every 20,000 km during maintenance of the vehicles. Ignition system breakdown is likely to occur when spark gaps reach 0.70 mm.

The selection of plug size in a retrofit engine is governed by the need for the spark plugs to fit into the restricted space available in the diesel injector recess. An independent monitoring of six CNG buses for one year covering 154,000 km gave an average consumption of 38.4 liter equivalent for 100 km. With an annual consumption of seven million liters of diesel fuel per annum, the conversion of six percent of the fleet has resulted in a ten percent reduction in diesel use. The imbalance comes from the fact that the CNG buses are more popular and often worked double shifts.

Gas prices and incentives were instrumental in furthering natural gas bus fleets in several countries. In New Zealand, the growth rate of fuelling stations was enhanced during the critical build-up phase by the provision of a 25 percent development grant on equipment.

For fleet operations, the prospect of lower fuel costs is a major driving force for the final acceptance of CNG as a vehicle fuel. The price actually paid for CNG at retail outlets needs to lie in the range of 55 - 65 percent of the fuel replaced if there is to be an economic incentive to convert. In general, if there are no tax or subsidy distortions and a rational marginal value basis for gas pricing, this situation will occur when the oil price is in the range of US$ 15-20 per barrel. When CNG prices fall below 50 percent of the fuel replaced, payback times for conversions become extremely attractive. It is difficult to institute and maintain an effective CNG program without the support of a consistent national natural gas pricing policy. (Shilton L.E., 1992).

3.1.1.4 Transperth Bus Operation in Australia

Transperth runs a fleet of 900 buses in Perth, the capital city of the State of Western Australia. Three buses were initially converted to CNG and the three buses have completed over one million km in eight years. In 1990, the company started to convert 30 buses using the engine manufacturer's lean burn technology. The success of the program has encouraged the company to convert the entire 900 buses to CNG.

A basic premise of the project was that the use of an alternate fuel should not interfere in any way on traffic operations. This goal was achieved. Refuelling was based on using compressors of about 650 M^3/hour capacity to slow fill buses overnight in their normal parking positions.

The price of natural gas in Western Australia is high, about half the price of diesel on an energy basis. Capital costs will be recovered over six years at present price levels. (Stephenson J., 1993)

3.1.1.5 Brisbane Transport Fleet Conversions

In March 1991, ten urban buses were converted to CNG and put in service. Two OEM buses were purchased and operated as part of the fleet. The cost of converting a diesel bus was estimated at A$ 42,000 and the cost of an OEM bus was A$ 23,000 more than the diesel counterpart including the cost of the cylinders.

Two compressors rated at 125 and 250 m^3/hour were installed with 1300 liter cascade storage. A refuelling time of 15 minutes was typical. Although this refuelling time may be acceptable for a small number of buses, it may not be adequate for large bus fleets.

Passenger reaction was favorable, and the noise levels were considerably reduced. **Drivers complained about the lack of power and acceleration.** The lack of on-road performance was mainly due to the speed gearbox not allowing the engine to work in the most favorable range. The OEM bus with a five speed gearbox performed better.

The CNG buses were about 19 percent heavier in fuel consumption than their diesel counterparts. Again, the OEM bus showed an improvement in this respect.

The breakdown rate of buses converted to CNG was high. The regulator was not reliable and some faults were observed with the ignition system and the low vacuum switches. (Weston G.R., 1992)

3.1.1.6 OEM Bus Fleets in Urban Centers of the U.S.A. and Canada

The U.S. Department of Transportation (DOT) sponsored a CNG bus fleet program that spans several cities in the U.S.A. and Canada. All the buses are powered by Cummins L-10 Natural Gas Engines. More than 265 vehicles are involved. The following table lists the cities where the buses operate, the number of buses in each city, the bus manufacturer and the total miles travelled by the buses as of May 1993.

Exhibit 3.3 CNG Buses in Service - May, 1993

PROPERTY	# OF BUSES	MANUFACTURER	TOTAL MILES
Mississauga	11	OBI/BIA	170,000
Toronto	25	OBI/BIA	1,600,000
Hamilton	30 10	OBI/BIA GM/IVECO	1,400,000
Chatham	2	OBI/BIA	8,000
Brooklyn	2	OBI/BIA	80,000
New Jersey	5	FLX	60,000 approx.
Colombia Gas	1	FLX	70,000 approx.
Cleveland	21	FLX	450,000 approx.
Dallas	2	FLX	80,000 approx.
Fort Worth	45	FLX	500,000 approx.
St. Louis	2	FLX	40,000 approx.
Dade County (Miami)	5	FLX	50,000 approx.
Reading	1	OBI/BIA	12,000
Pittsburgh	5	OBI/BIA	190,000
Tacoma	30	OBI/BIA	1,000,000
Salt Lake City	5	OBI/BIA	100,000
SCRTD (LA)	4	FLX	200,000 approx.
NCTD (LA)	6	FLX	140,000 approx.
OCTD (LA)	2	GILLIG	80,000 approx.
Galviston	1	FLX	
Binghampton	3	OBI/BIA	
Syracuse	8	OBI/BIA	
Rochester	5	OBI/BIA	
Buffaloe	5	OBI/BIA	
Mineola	10	OBI/BIA	
Yolo	4	OBI/BIA	
Sacaramento	15		
TOTAL	265		

The Toronto Transit Commission (TTC) Report evaluated the operation of the 25 CNG buses as of August 1992. Vehicle availability is a measure of vehicle reliability and ease of repair. It is based on the total number of vehicles that are available for service. During the evaluation

period, the 25 buses were available 92.05 percent of the time. Only 20 percent of the time the vehicles were not available for service was specifically related to the use of CNG. This is considered to be quite acceptable for a major development project.

Over the evaluation period, the average cost per m^3 of natural gas was $ 0.01357 and the electrical "cost of compression" was $ 0.017 per m^3. The cost of operating the CNG buses and the compression station was $ 0.295 per mile. If the provincial road tax is applied, the operating cost per mile would be approximately $ 0.295 per mile. In comparison, the cost per mile to operate a new Diesel bus is $ 0.399 per mile.

Cummins Engine Company has confirmed that their L-10 CNG Engine will be certified to the California Air Resources Board (CARB) Standard.

Ignition system problems accounted for 15 percent of all repairs/inspections of the CNG buses and the life of the spark plug and ignition wiring has been unacceptably short. Recent selection of the spark plug and ignition wiring appears to have solved the problem.

Vehicles running out of fuel while in service was the most prevalent issue. Installing a low fuel warning light that comes on when the cylinder pressure falls below 500 psi has eliminated this problem.

Since the CNG engines are turbocharged, there is approximately a 40 percent increase in power output. The CNG engines have more power and run quieter than comparable diesel engines. The following table is a cost comparison of the diesel and CNG buses operating on similar routes and compiled by the Toronto Transit Commission.

Exhibit 3.4 Diesel Versus CNG Fuel Cost Comparison

	DDC 6V-92TA Diesel	Cummins L10 Diesel	Cummins L10 CNG	
			25 Buses	125 Buses
Fuel Price ($100l or m³)	$40.0 +	$40.0 +	$19.4	$16.4
Fuel Consumption (l or m³/100 km)	58.8 +	43.5 +	72.9 *	72.9 *
Fuel Cost ($/100km)	$23.52	$17.40	$14.14	$11.95
Annual Fuel Cost ($) for 84,000 km +	$19,757	$14,616	$11,880	$10,038
Savings ($) Relative to 6V-92TA	$0	$5,141	$7,877	$9,719
Savings Relative to L10 Diesel	($5,141)	$0	$2,736	$4,578
Savings (%) Relative to 6V-92TA	0%	26%	40%	49%
Savings (%) Relative to L10 Diesel	-35%	0%	19%	31%

* -50.7 kg/100km = 72.9 m³/100km
\+ -TTC supplied figures

3.2 Experience in Egypt

In Egypt, the **Organization for Energy Conservation & Planning, (OECP) Ministry of Petroleum,** completed a study in 1991 assessing the costs and benefits of substituting natural gas for diesel (gasoil) in the transport sector. Diesel consumption (2.99 million metric tons of oil equivalent) in the transport sector constituted 49.7 percent of total diesel consumption for fiscal year 1990/1991. Diesel oil consumption by different vehicular modes of travel was as follows:

Trucks & Buses	97.0 percent
Ferry & barges	1.6 percent
Railroads	1.2 percent

The design of refineries in Egypt are such that without the addition of a hydro-cracker unit, the refineries cannot produce all the diesel oil needed to meet domestic demand. Hence a fair share of diesel oil demand is met by foreign imports. Domestically produced natural gas can substitute for diesel oil in trucks and buses. Since domestically available natural gas has not been an internationally traded commodity, its substitution for imported diesel oil, which is readily tradeable internationally, would yield economic and environmental benefits to the country. Note that the great increase in natural gas reserves may lead to export of the fuel for Egypt.

The positive assessment by OECP formed the basis for international agencies to consider follow-on studies.

Some of the joint venture petroleum companies PETROBEL (EGPC and AGIP) and GUPCO (EGPC and AMOCO) in Cairo have already introduced dedicated CNG buses and bi-fuel fleet passenger cars. NASCO is planning on mounting bus bodies on five imported IVECO natural gas engines/chassis. Carlin Middle East has submitted a quotation to GUPCO for a "Bluebird" school bus fitted with a "Tecogen" dedicated natural gas engine.

Of interest also is the corporate decision reportedly taken by AMOCO headquarters in Chicago. After an assessment of its world wide business opportunities for the long term, AMOCO has decided on investing in the exploration, distribution and management of natural gas in Egypt. In support of this strategy, AMOCO has submitted an ambitious proposal for a large scale conversion of Cairo vehicles to natural gas to the Minister of Petroleum.

Other evidence of the government's commitment to use natural gas in the transport sector is the number of natural gas filling stations that are either planned or in operation. PETROBEL has a mobile and a stationary filling station operating in Cairo. AMOCO has two stationary filling stations in operation and two are under construction.

In 1992, UNDP funded a study of the feasibility of CNG conversions of 100 buses of the Greater Cairo Bus Company's fleet. The author of that study recommended against CNG conversion in that case primarily because of the age of the engines and concerns about the operational and technical difficulties associated with converting the types of engine they use.

3.3 Conversion Technology

By the conversion of CNG, we mean both the retrofit of existing engines to use CNG and the use of new engines or vehicles that are manufactured specifically for CNG use. In this section, we briefly summarize the technological status of CNG vehicles. For clarity, the following definitions apply here:

- "Retrofit" refers to the modification of an existing engine by changing or adding a few components so that CNG fuel could be used. Generally, retrofits do not have factory warranty.

- "New Engine" refers to a factory built engine by an Original Equipment Manufacturer (OEM) that is designed and warranted to operate on CNG.

- "Dedicated CNG Engine or Vehicle" - The engine uses only compressed natural gas (CNG) as the fuel. This could be retrofit or a new engine.

- "Dual-Fuel Engine, Open Loop Controlled" - applies to conversions of diesel engines only. The existing fuel system is kept intact while a CNG fuel system is added. Both fuels are used in proportions varying according to the engine

load. Use of 100 percent diesel fuel is possible, but use of 100 percent CNG is not possible.

- "Dual-Fuel Engine, Closed Loop Controlled" is a variation of dual-fuel engine in which the diesel fuel system is small and limited to provide a pilot ignition source for the CNG fuel. The engine can idle but can not provide any significant power on diesel fuel alone.

- "Bi-fuel Engine" - Engine that would operate on either gasoline or CNG fuel, but never on both fuels. The fuel switch could be either manual or automatic.

3.3.1 Conversion of Gasoline-Powered Engines and Vehicles

Virtually all passenger cars and light-duty trucks in Egypt are powered by gasoline engines. These engines are spark-ignited and have compression ratios reasonably compatible with compressed natural gas (CNG) fuel: the compression ratio is about 10:1 compared to 14:1 to 13:1 in most diesel engines. The optimum compression ratio for natural gas vehicles is around 11:1. Conversion of gasoline engines to CNG fuel is discussed in this section.

3.3.1.1 Retrofit of Existing Gasoline-Fueled Vehicles

This is a decades-old technology used in a number of countries successfully, but never in a mass production scale. No internal engine changes are needed. The fuel tank for CNG is a pressure vessel in which the gaseous fuel is stored at 3,000 psi (pounds per square inch) 200 bar pressure. The major effort in retrofits is properly installing the fuel tank in the vehicle while conforming to safety standards. The carburetted engine is the most common type (as compared to fuel injected type) in Egypt. For retrofit conversions in Egypt, carburetors should be replaced with natural gas fuel mixers. Such mixers can be purchased readily in most developed countries. Retrofits can be either dedicated CNG systems or bi-fuel systems.

3.3.1.1.1 Dedicated CNG Retrofit Conversion of Gasoline-Fueled Vehicles

Exhibit 3.5 shows a schematic diagram of the fuel system for a dedicated CNG vehicle. Because the carburetor operates at close to atmospheric pressure, the fuel pressure, which is 3,000 psi in the cylinders, must be reduced through a two or three stage pressure regulator system for use in the engine. While the engine will operate satisfactorily without any compression ratio change compared to its gasoline version, dedicated CNG engines offer an opportunity to increase the compression ratio, and hence thermal efficiency. This is possible due to the increased octane number of CNG. Other engine modifications that are desirable include spark timing and spark plug gap optimization for CNG, cylinder head redesign for improving volumetric efficiency and a hardened valve seat to avoid seat recession and improve durability. However the cost of conversion increases with every additional change. Typical cost estimates for converting a gasoline vehicle to dedicated CNG are as follows:

U.S. Conversions	$1,100 to 1,700 per vehicle
Egyptian (Petrobel) Conversion, electronically controlled (i)	$ 720 per vehicle
Egyptian Conversion, mechanically controlled (ii)	$ 550 per vehicle

It should be noted that U.S. conversion kits are more complex due to the emissions certifications needed and the electronically controlled combustion in U.S. vehicles. In addition, U.S. vehicles are generally larger and contain two CNG cylinders. The Egyptian conversion estimates above provided by Petrobel are for carburetted engines (i) with and (ii) without some electronics. Considering the passenger car population in Egypt, it is reasonable to assume that most cars will be smaller and have carburetors. The Petrobel estimate assumes only one CNG cylinder is needed per vehicle.

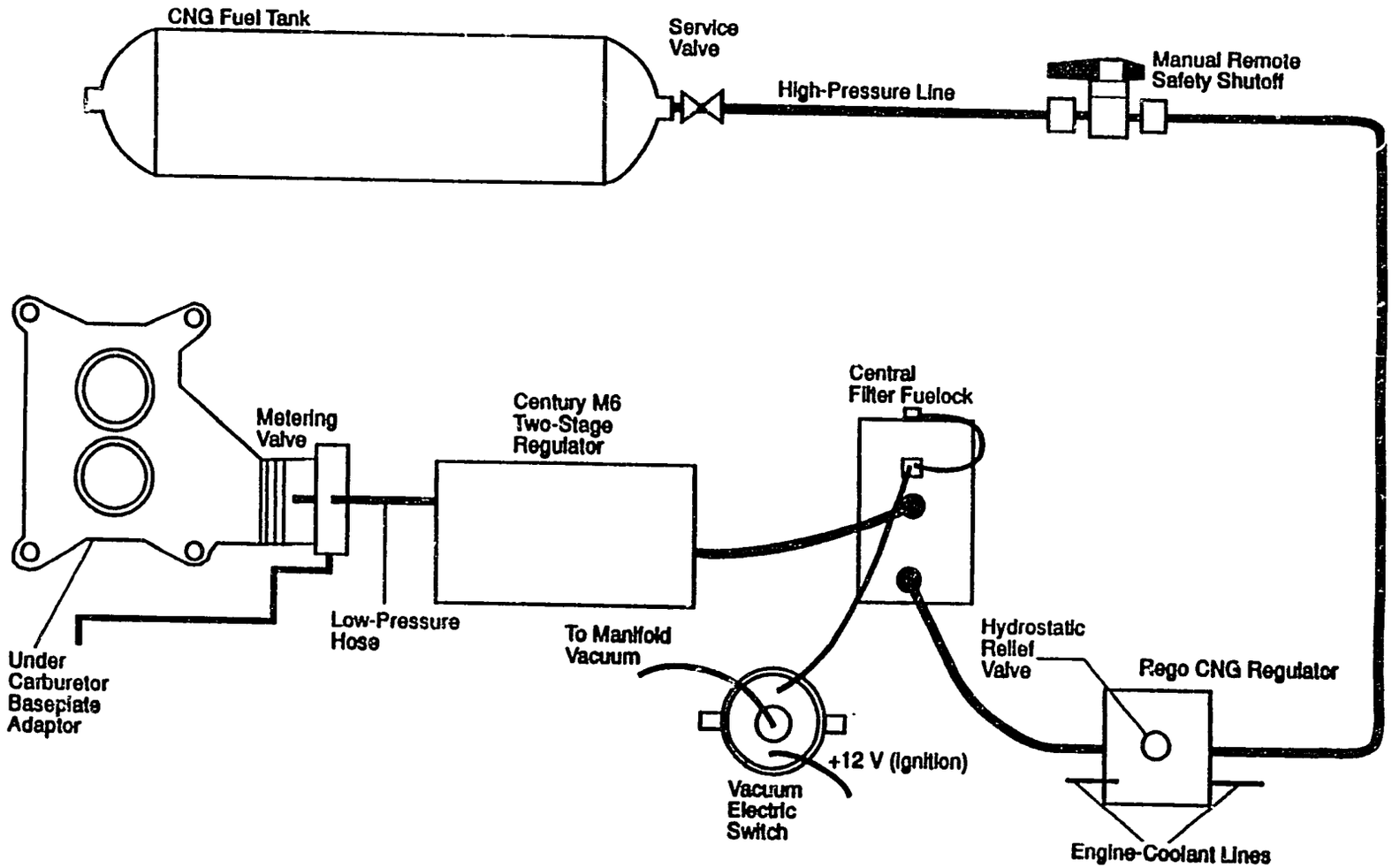
The main problem of the dedicated CNG vehicle is the limited range compared to its gasoline counterpart. In order to maintain the same range between refills, too many CNG cylinders will be needed resulting in excess weight and cost. In addition, until the refueling infrastructure is in place, a CNG vehicle driver may worry about running out of fuel at inconvenient times and places.

3.3.1.1.2 Bi-fuel Conversions - Gasoline Engine Retrofit

As far as technology is concerned, bi-fuel conversion is identical to dedicated CNG conversion except that the gasoline fuel system is left in place. A driver-operated switch controls which fuel, gasoline or CNG, is directed into the carburetor. The advantage of the bi-fuel system is that the vehicle range between refueling is not a problem. However the engine performance and vehicle emissions are compromised to operate on two different fuels and the added weight of carrying two types of fuel tanks must be considered. When CNG fuel is used, the spark-ignition timing should be advanced for proper operation. It is impossible to change spark timing in non-computer controlled, carburetted engines when fuels are switched by the driver. While the engine will run on both fuels, it will not run with optimum efficiency on either fuel. The cost of conversion is slightly higher than in the case of dedicated conversion since two fuel systems are in place and the fuel selection controls are additional components. For dedicated or bi-fuel conversions, the gas-air mixture is throttled as it enters the engine intake manifold. For an engine with an electronic (or, computer) controlled combustion system, one of the problems is the stoppage of gasoline flow to the engine. It has been reported that stoppage of gasoline flow in order to initiate CNG flow can send error codes to the computer.

One major advantage of passenger car applications of CNG in Egypt is that there are no catalytic converters. If CNG is used extensively in these vehicles, it is conceivable that the country could avoid the need to go to catalytic converters to achieve acceptable emissions levels.

Exhibit 3.5. Schematic Diagram of a Fuel System for a Dedicated CNG Vehicle



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3.3.1.2 New Engines

New engines and vehicles to operate on CNG fuel are always preferable over piece-meal conversions in terms of performance, efficiency, emissions, and warranty. A fully optimized and properly designed vehicle built in the factory with full warranty will be more readily accepted by end-users. All the major vehicle manufacturers in the U.S. currently offer a few selected models of CNG vehicles. Generally, the automobile manufacturer builds the gasoline version of the vehicle in the conventional manner using factory assembly lines. A selected number of these vehicles, consistent with the immediate market demands, are taken to a secondary assembly line for upfitting with CNG-related parts. The components of the new engine are conceptually the same as the retrofit systems; the same functions are performed, although more optimally.

3.3.2 Conversion of Diesel Engines

3.3.2.1 Retrofit Diesel Engines

Nearly all buses and heavy-duty trucks are powered by diesel engines in Cairo. Diesel engines are the most efficient, durable and economic power plants used worldwide. But smoke, particulate and NO_x emissions from diesel engines are of concern. An existing diesel engine can be converted to operate on CNG fuel but the conversion is more expensive than in the case of a gasoline engine. This is due to the fact that CNG fuel can not be used in engines with compression ratios (CR) higher than 11:1, whereas diesel engines have compression ratios of 14:1 or higher. In order to change the compression ratio a major engine overhaul, including a change of pistons, is necessary. This makes a diesel engine retrofit more expensive than a gasoline engine retrofit. Usually a retrofit conversion does not have factory warranty.

3.3.2.1.1 Dedicated CNG Conversions - Diesel Engine Retrofit

An existing diesel engine with CR of 14:1 or higher can be converted to operate on CNG fuel alone by making the following changes:

Remove the diesel fuel system and replace it with a CNG-air mixer, similar to a carburetor in a car. Adapt the fuel injector holes in the cylinder head to provide spark-plugs. Change the pistons to low-CR pistons. Design a CNG fuel tank and a multi-stage pressure reduction system. Test the engine and establish the new power ratings with CNG fuel. Generally, a rated power reduction of 15 percent - 20 percent should be expected with CNG, especially in a naturally aspirated engine. This derating is unavoidable due to the fact that in a fixed displacement engine, gaseous fuel occupies more of the combustion chamber space than diesel fuel resulting in less air available for the combustion process.

This conversion of diesel engines is well known and no new technology needs to be developed, although the conversion "kits" for each engine require some engineering. In small quantity conversions (1 to 10 engines per batch), the cost is estimated to be $5,000 per engine. Since Egypt has manufacturing capability for Deutz air-cooled engines, a design and layout project for

a specific Deutz engine would be necessary. The main advantage of dedicated CNG conversion is the total elimination of the diesel fuel system. Also this is the most economical conversion of a diesel engine and provides the maximum benefits of the CNG fuel.

3.3.2.1.2 Dual Fuel Diesel Engine Retrofit

There are two types of dual fuel system retrofits. In the first, the diesel fuel system is kept intact and a CNG mixer is added. The compression ratio is unchanged and the diesel fuel provides the ignition source. Both fuels are used simultaneously with the actual proportion of CNG based on engine load factor. Generally at high loads, CNG is the primary fuel with about five percent diesel fuel. At idle and low loads, a greater proportion of diesel fuel is used. The engine retains the option of diesel fuel-only operation. One hundred percent CNG operation is not possible due to the absence of an ignition source and the high compression ratio. In the second system type, called pilot ignition natural dual fuel engines, a small but constant amount of diesel is added regardless of load. The cost of dual fuel retrofits is likely to be lower, because major engine overhaul is not necessary. The estimated cost of conversion to a dual fuel configuration is $4,000 per engine in low volumes. The main advantage of the dual fuel engine is that the capability of diesel fuel operation is fully retained. This, however, opens the possibility of the operator never using CNG, except for the pilot ignition dual fuel system in which the engine can only idle with diesel. Two fuel systems need to be maintained and two types of fuel tanks must be carried.

3.3.2.2 New Diesel CNG Engines

Use of new, factory-built CNG engines based on a diesel engine design and intended to be used in heavy-duty applications is the technically preferred approach for changing over to CNG fuel if funds are available. New engines come with a factory warranty similar to current production engines. Actual changes made to engines in the factory are the same as in the case of retrofits. These new engines can be dedicated CNG fuel only or dual fuel type. In either case the volume of production based on market demand must grow to a fairly large number before capital investment could be justified. Initially, when volume of production is low, a job-shop type factory using diesel engine blocks and other major components could match the demand. This is similar to an engine rebuild center where an economical mix of good quality used parts and new parts are used to build CNG engines that can be warranted.

3.3.3 Original Equipment Manufacturers (OEMs) in the U.S.A.

Currently, there are several original equipment manufacturers producing fleet type vehicles in the U.S.A. Ultimately, vehicles will be dedicated NGVs and will be optimized for both engine performance and emissions.

As manufacturers move from early-entry vehicles towards optimized NGVs, the engines will be designed to take advantage of the fuel characteristics of the natural gas, and computerized fuel management systems for natural gas vehicles will be developed. Additionally, on-board fuel storage cylinders will be lighter in weight than the cylinders available today.

The following table, Exhibit 3.6, illustrates the types of fleet type transit and shuttle buses that are in the market:

Exhibit 3.6 Original Equipment Manufacturer NGVs Available for Purchase

(Source: NGV Institute, Las Vegas, Nevada)

ORIGINAL EQUIPMENT MANUFACTURER NGVs AVAILABLE FOR PURCHASE		
VEHICLE TYPE	**Bi-Fuel, Dual-Fuel or Dedicated Natural Gas**	**ENGINE TYPE/ SIZE**
Champion Motor Coach Challenger	Bi-Fuel	Ford 5.7 Liter or 7.5 Liter
Champion Motor Coach Champ	Bi-Fuel	GM 4.3 Liter or 5.7 Liter
El Dorado National RE-29 Transit.Paratransit	Dedicated	Hercules 5.6 Liter
Flexible Metro	Dedicated	Cummins 10 Liter
Gillig Phantom (Liquefied Natural Gas)	Dedicated	Cummins 10 Liter
Goshen Coach GC II	Bi-Fuel or Dedicated	Ford 7.5 Liter
Goshen Coach Sentry ML	Bi-Fuel or Dedicated	GM 7.4 Liter
Goshen Coach Para-Transit	Bi-Fuel or Dedicated	Ford 7.5 Liter
Neoplan USA Transliner (6 models ranging from 40 to 45 feet)	Dual-Fuel or Dedicated	DDC 6V92 PING, DDC 6V92 DING or DDC Series 50G
Neoplan USA Metroliner (2 models ranging from 40 to 45 feet)	Dual-Fuel or Dedicated	DDC 6V92 PING, DDC 6V92 DING or DDC Series 50G
New Flyer D-40	Dedicated	DDC 6V92 DING, Cummins 10 Liter or DDC Series 50 SING
Stewart & Stevenson T-40 Apollo (compressed or liquefied natural gas)	Dual-Fuel	DDC 6V92 PING
Transportation Manufacturing Corp. RTS	Dedicated	Cummins 10 Liter or DDC 6V92 DING
Non-Road Vehicles		
Clark material Handling (8 sizes/types of fork lifts)	Dedicated	Mitsubishi 1.6 Liter, 2.0 Liter, 2.4 Liter; Continental 2.7 Liter; Perkins 3.9 Liter; Ford 4.9 Liter; Ford 7.5 Liter
Dig-It Manufacturing 158 N Backhoe	Bi-Fuel or Dedicated	Kohler Magnum 2 cylinder
Yale Material Handling (4 sizes/types of fork lifts)	Dedicated	Yale 4 cylinder
Passenger Cars		
Chevrolet Caprice (1995 model year)	Bi-Fuel	GM 4.3 Liter
Chevrolet Corsica	Bi-Fuel	GM 2.2 Liter
Light-Duty Pickup Trucks		
GMC Full-size Truck (1995 model year)	Bi-Fuel	GM 5.7 Liter

ORIGINAL EQUIPMENT MANUFACTURER NGVs AVAILABLE FOR PURCHASE		
VEHICLE TYPE	Bi-Fuel, Dual-Fuel or Dedicated Natural Gas	ENGINE TYPE/ SIZE
Chevrolet (1995 model year)	Bi-Fuel	GM 5.7 Liter
Vans		
Dodge B250 Van and Ram Wagon (3/4 ton)	Dedicated	Chrysler 5.2 Liter
Dodge B350 Van and Ram Wagon (1 ton)	Dedicated	Chrysler 5.2 Liter
Dodge Caravan (mini-van)	Dedicated	Chrysler 3.3 Liter
GMC Truck/Chevrolet Full-size Van (1995 model year)	Bi-Fuel	GM 5.7 Liter
Other Trucks		
Crane Carrier LET Refuse and Recycle Chassis	Dedicated	Cummins 10 Liter, Hercules 5.6 Liter or TacoDrive 7.0 Liter
GMC Truck Top Kick (1995 model year)	Bi-Fuel or Dedicated	GM 7 Liter
Chevrolet Kodiak (1995 model year)	Bi-Fuel or Dedicated	GM 7 Liter
GMC Truck/Chevrolet P-Chassis (1995 model year)	Bi-Fuel	GM 5.7 Liter
School Buses		
Blue Bird TC/2000 All American (Front or Rear Engine)	Dedicated	TecoDrive 7.0 Liter or Hercules 5.6 Liter
Carpenter Counselor	Dedicated	Hercules 5.6 Liter
GMC Truck/Chevrolet School Bus	Dedicated	GM 7.0 Liter
Thomas Built Saf-T-Liner MVP	Dedicated	Hercules 5.6 Liter
Transit and Shuttle Buses		
Blue Bird Body Company Q-Bus	Dedicated	TecoDrive 7.0 Liter
Bus Industries of America/Orion V/CNG	Dedicated	Cummins 10 Liter
Champion Motor Coach Centurion	Bi-Fuel	GM 7.0 Liter
Champion Motor Coach CTS	Bi-Fuel	GM 7.4 Liter

3.4 CNG Cylinder Technology

There are four types of materials certified by the U.S. Department of Transportation used for on-board gas fuel storage cylinders on natural gas vehicles. The four materials are:

- Steel
- Steel composite
- Aluminum Composite
- All-composite

Steel composite and aluminum composite cylinders are made of steel or aluminum and wrapped with fiberglass. All-composite cylinders are made from a high-density polyethylene liner with carbon fiber and fiberglass or epoxy resin and fiberglass covering.

In the U.S., cylinders are manufactured, tested, and certified, and must be used in accordance with U.S. Department of Transportation (DOT) or Transport Canada (TC) regulations or ANSI/AGA NGV2 standards. All cylinders manufactured to DOT or TC specifications must be recertified. Steel cylinders must be recertified every five years and steel composite and aluminum composite cylinders must be recertified every three years. Cylinders manufactured to ANSI/AGA NGV2 specifications will have a 15 year useful life with no requirement for re-certification.

Aluminum and steel composite cylinders weigh 30 percent to 70 percent less than steel cylinders. All-composite cylinders weigh up to 80 percent less than steel cylinders. All four types of cylinders will accept natural gas at pressures ranging from 2400 psi to 3000 psi.

The following table, Exhibit 3.7, compares similar sizes of four types of cylinders.

Exhibit 3.7 A Comparison of On-Board Fuel Storage Cylinders
(Source: NGV Institute, Las Vegas, Nevada)

MANUFACTURER	SIZE	CAPACITY	WEIGHT	100+ QUANTITY PRICE
ALL-COMPOSITE NGV-2				
EDO	12" X 38"	525 SCF	39 lbs.	$725
Brunswick	13.7" x 35"	503 SCF	56lbs.	$595
FULLY-WRAPPED ALUMINUM COMPOSITE				
Comdyne I, Inc.	13" x 38"	513 SCF	84.3 lbs.	$613
SCI	13.5" x 34"	487 SCF	78.3 lbs.	$487
HOOP-WRAPPED ALUMINUM COMPOSITE				
CNG Cylinders	13" x 35"	462 SCF	89 lbs.	$518
HOOP-WRAPPED STEEL COMPOSITE				
Pressed Steel	13" x 35"	567 SCF	134 lbs.	$602

Currently, the recertification procedure for the non-NGV2 on-board storage cylinders requires that the cylinders be removed from the vehicles and taken to a facility approved by DOT to re-certify by hydrostatically testing the cylinders to ensure that they maintain pressure and that there are no leaks or stress cracks. This process is being examined through a GRI-funded program to

apply an acoustic emission process to metallic on-board cylinders with the hope of reducing and simplifying the cost of recertification.

3.5 CNG Filling Station Technology

Refueling stations constitute a major capital investment item in switching the transportation sector to CNG. There are two types of filling stations: fast fill and slow fill systems. Fast fill stations are considerably more expensive than slow fill stations. The fast fill station is equipped with a compressor or set of compressors, high-pressure storage, and dispensers. Slow-fill stations do not have a high pressure storage system. There are two types of fast fill dispensers: mechanical and electrical. The electrical dispenser is used when an accurate reading of the amount of fuel dispensed to each vehicle is needed. The mechanical dispenser is much cheaper, but does not have accurate flow recording capabilities. The compressor and dispenser technologies have been demonstrated in Egypt, although not manufactured there. GUPCO has two operating CNG stations and two more are planned. PETROBEL also has two operating stations. The major determinants of the cost of the station are the proximity and the pressure of the CNG source. The exact trade-off of compressor size, number of compressors, and storage size requires a detailed engineering/ economic analysis, the result of which will have a strong impact on the economic viability of the fleet CNG application.

Fleet operators can have a central refueling station which could be of the slow-fill type, if the vehicles are parked for an adequate period of time every night. In some cases, a mix of slow-fill and fast-fill refueling is appropriate.

A truck can be equipped with a large storage cylinder to provide an emergency supply of CNG to resupply vehicles caught out on the road. The cylinder on this truck need only be sized large enough to provide enough CNG to get the vehicles back to the refueling station.

One must be very careful of costs cited for refueling stations because the costs are very sensitive to size and type. Conceptual cost estimates for refueling applications for specific fleet applications have been developed for this report and are presented in later sections. These costs always represent a very large portion of the total investment in any CNG fleet.

The design and selection criteria for CNG fuelling station components are complex partly because station operation must reflect the operation of established liquid (gasoline and diesel) fossil fuel stations. CNG customers often expect that same ease and speed of operation with gasoline and diesel filling stations and the opportunity to travel relatively long distances between fills. Satisfying this customer expectation necessitates large compressors with high rates of CNG output at very high pressures. Gas at high pressure and volume requires large, heavy, and expensive storage vessels.

In 1992, a fast fill station to refuel 10 transit buses per hour for the Toronto Transit Commission was budgeted to cost approximately US $2.5 million. Specifications were developed for fast filling a fleet of 125 CNG buses (about 240 m^3) of natural gas per vehicle giving a range of 370 km. The station is the largest and most advanced in Canada.

If gas from a compressor is pumped directly into the vehicle storage cylinder, the compressor works against a steadily rising back pressure. This process calls for the minimum amount of work needed for compression.

However, if a compressor fills a storage cascade and the storage bank is connected to the cylinder on the vehicle, a part of the compression work is wasted in the initial filling process because high pressure gas is "throttled" to a lower pressure of an almost empty vehicle cylinder. A throttling process in thermodynamic systems is an adiabatic, not an isentropic process and is associated with a loss of energy. This loss can be minimized if gas is stored in banks, also called storage cascades, with each storage tank of the system maintained at different pressure levels. The empty vehicle cylinder can be connected sequentially to banks at increasing pressures. The main purpose of multi-level storage is to optimize the availability of gas for fast filling at a fuelling station and not to optimize the energy needed for compression.

In a slow fill operation, the gas in the cylinder has time to reach equilibrium with the ambient temperature. Therefore maximum storage is achieved for given cylinder pressure. In the case of the fast fill, due to the rapid rate of filling, the temperature rises in the cylinder and takes several hours to return to equilibrium with the surrounding temperature. When the equilibrium in temperature is reached, the actual pressure of the cylinder is lower than the pressure at which it was filled. This problem with fast fill can be remedied by pre-cooling the gas before it reaches the dispenser. Another strategy might be to stipulate a higher pressure for the fast fill than the slow fill at the same station.

In one case, three different refuelling systems were tested to establish the "Storage Utilization Factor". The three systems were:

- Uniform Pressure Storage
- Sequential refuelling system
- Booster Assisted Refuelling

Storage Utilization Factor is defined as the ratio of the total gas volume delivered to the vehicles to the total volume held in the station storage at 3600 psi. If the compressor was operating during vehicle refuelling, the volume delivered by the compressor was deducted from the volume delivered before calculating the utilization factor.

The booster banks had two storage banks (2418 liters for the "low" bank and 806 liters for the "high" bank). The booster was used to keep the high bank pressure as high as possible. With this system, the number of fills for the 240 liter vehicles rose from six vehicles for the sequential cascade system to 14 vehicles, and the storage utilization factor was increased from 31 percent to 60 percent.

The metering of gas supplied to filling stations may be based on the Coanda effect to measure the volumetric flow rate and on the coriolis effect to measure the mass flow rate. Mass flow rate meters are particularly successful. Based on energy equivalency, the popular measure might be the gasoline gas equivalent.

Until quite recently, there were approximately 10 different filling connections (the receptor for the gas in the vehicle and the nozzle from the dispenser). Only recently has the American Natural Gas Standards Institute (ANSI) established the NGV 1 code (standards) for the receptor and the nozzle (filling connections).

A CNG filling station includes the following equipments:

- **Compressor and Drive;**
- An electronically controlled **Priority Panel** that controls the fuel flow from the compressor to the high pressure storage cascades;
- **Emergency Shutdown Device;**
- **Sequential Panel** that manages the fuel flow from the storage cascades to the vehicle; and
- **Dispensers.**

At a fast fill or slow fill CNG station, the natural gas vehicle is normally fueled by either the high-pressure storage cascades or the buffer storage system. The pressure difference that exists between the fuel in the storage cascades and the cylinders on-board the vehicle is used to fill the vehicle. A slow fill station usually takes from 6-8 hours to fill a heavy duty vehicle while a fast fill station can fuel the same vehicle in 3-5 minutes.

There are normally three banks of compressed natural gas pressure vessels or tanks, called storage cascades, at a fueling station. All these tanks at the filling station are maintained by the station compressors at a pressure (3600 psi) that is higher than the pressure to which the cylinders on-board the vehicle are to be filled (3000 psi).

When a vehicle pulls into a CNG station for gas, CNG from the initial tank ("low") of the storage cascades starts the fuel filling process. At the start, the initial pressure difference between the "low" tank and the cylinders on-board the vehicle is at the maximum; and consequently, the CNG from the "low" tank to the cylinders on-board the vehicle starts at the maximum rate of flow. As the filling process continues, the rate of CNG flow steadily drops because the difference in pressure between the "low" tank and the cylinder is steadily reduced. At a set pressure of the "low" tank, the Sequential Panel, automatically switches the CNG flow from the "low" tank to the "medium" tank at 3600 psi. The flow rate starts at a high rate. After some time, the flow rate from the "medium" tank to the cylinders declines and at a pre-set pressure of the "medium" tank, the sequential panel brings the "high" pressure tank on line until all of the cylinders on the vehicle are filled at 3000 psi. The Priority Panel manages the gas from the compressors and supplies the gas to the storage banks in the priority sequence "high", "medium", and "low".

Section 4.0 Description of the Cairo Vehicle Population, Fuel Supply, and Pricing

4.1 The Cairo Vehicle Population

An important aspect of the data gathering phase of this study was collecting as much information as possible about the vehicles in Cairo to determine quantity, vehicle types, engine types, fuel usage, maintenance characteristics, and so forth. Selection of specific vehicles for more detailed analysis of conversion potential must be based on an understanding of the vehicle "universe" within the city.

Exhibit 4.1 lists the number of vehicles that operate in the three Governorates comprising the Cairo metropolitan area in relation to the total number of vehicles licensed to operate in the country. These data were taken from a March 1994 table provided by the Traffic Department which listed vehicles by type for all governorates. The larger source table can be found in an Appendix. Some of the vehicles listed in Exhibit 4.1 are not grouped by type of vehicle but by ownership, such as "governmental" and "public sector." Nonetheless, a good approximation of the relative size of major vehicle type populations can be derived.

The Governorate of Cairo, Kalyoubia and Giza, which together constitute the Cairo metropolitan area, contain more than 47 percent of the total number of vehicles registered in the country.

Other important characteristics of the vehicle population can be determined through fuel usage data. Data provided by the Ministry of Petroleum indicate that gasoil or diesel use exceeds gasoline consumption and represents about 47 percent of the total fuel used for the transportation sector. Gasoline represents about 38 percent.

From Exhibit 4.1, it can be seen that trucks far outnumber buses. Public transportation buses in Cairo predominantly belong to either the Cairo Transportation Authority (CTA) or the Greater Cairo Bus Company (GCBC). These groups were very cooperative in providing detailed characterization of their fleets. These detailed data are provided in a later section of this report where they are used as the basis for inputs to the economic model. The bus fleets are an obvious candidate for consideration of CNG conversion.

Much of the additional data concerning the vehicle fleets were obtained through various sources in a more "piecemeal" fashion. An extensive discussion of sources and specific data is not possible in the time available. Some important observations are:

- There are essentially no diesel-powered passenger cars in Cairo, as these were prohibited by law for the public.
- Because of the very low price of diesel fuel, almost all trucks and buses are diesel powered. There are essentially no gasoline-powered trucks or buses.

- Vehicle types with the greatest expected growth rate over the next few years are passenger cars and microbuses. The number of public buses has not been expanding at a great rate due to capital constraints. The rate of increase in the number of private vehicles is declining relative to the very high rate of the 1980s. Growth rates are now around eight percent per year.

- The average life of passenger cars in Cairo is approximately 20 years. The high capital cost of a vehicle relative to personal income leads to long retention by their owners. The quality of maintenance and state of repair of passenger cars is highly variable. Many receive poor routine maintenance and only go to the shop upon failure. The vast majority of cars use 1970 technology, or earlier, and have no pollution control equipment. Most cars are very small and have small engines (less than 2 liters displacement) due to heavy taxes on larger engines.

- Very little data could be obtained on the microbus or minivan population in the time available for this study. These vehicles are considered part of the taxi fleet but operate more like small buses. Both diesel and gasoline engines are used. The microbuses are heavily utilized by the public, generally run regular routes each day and they have high annual mileage rates. These vehicles are not operated in fleet fashion. Generally, they are owned and operated by individuals and kept at individual residences when not in use.

- The taxi population is high and is primarily made up of vehicles owned and operated by individuals who keep them at their residences when not in use. Taxis are usually better maintained than private cars due to the owners' reliance on them for income. However, they generally have higher usage rates. Very little recent data (past 1985) could be found describing the taxi population.

- The heavy-duty truck population in Cairo, as mentioned above, is large. Heavy trucks are excluded from downtown Cairo during the daytime. Little data were found to describe other characteristics of the truck population. Again, most are believed to be owned and operated by individuals. It is believed that most heavy duty truck owners would be unwilling to restrict the possible range of operation for their vehicles to the Cairo area. Several delivery truck fleets were identified during the data gathering phase of this study. These are discussed later and they offer the best potential among trucks for early CNG conversion.

Exhibit 4.1 Statistical Data on Vehicles in Egypt [1]

March 1994

VEHICLES	Motor Cycles	Passenger		Buses			Trucks	Taxi
		Public	Private	Public	Private	Tour		
Governorate								
Cairo	92571	33421	435163	4276	4649	3022	84524	41264
Katyoubia	26250	2155	17410	232	720	290	18200	17410
Giza	35440	1708	146083	370	2044	310	34132	27825
TOTAL Cairo	154261	37284	598656	4878	7413	3622	136856	86499
% of Total	42.4	60.7	63.3	42.6	43.1	70.3	35.1	40.5
TOTAL Egypt	363868	61393	945848	1148	17195	5154	390222	213579

[1] For complete Statistical Table, refer to Appendices.

Source (The Statistical Section, Ministry of Interior, General Traffic Department, Government of Egypt, March 1994)

4.2 Natural Gas Supply

Based on discussions held with host country officials, AID representatives, private sector groups, and members of the World Bank Group visiting Cairo, the proved natural gas reserves in Egypt seem real and substantial. Presently, natural gas supplies to electric power plants represent over 70 percent of the total fuel needs of thermal power stations. Not all electric power stations can be supplied with or switched to natural gas. By the year 1998, almost all of the fuel supply for the electric sector is expected to come from domestic natural gas fields.

For the period 1994-1998, the domestic natural gas supplies are expected to be tight and just enough to meet the anticipated demand from the industrial, household, and electric sectors. This is because not all natural gas fields have been developed.

After 1998, natural gas supplies are expected to exceed projected demand. Therefore, the Datex team was encouraged by the World Bank Group to plan for maximum utilization of natural gas in the transport sector because the maximum demand from the transport sector will still be a small part of the total demand.

There are three natural gas fields from which distribution lines reach Cairo. The fields are located at: Abu Maadi, Abu Quir, and Abu Ghardig. Presently, Abu Maadi and Abu Quir are the principal suppliers while natural gas from Abu Ghardig has yet to be linked to the natural

gas loop for Cairo. The composition of the natural gas from these fields is given below:

Exhibit 4.2 Composition of Natural Gas for Cairo Vehicles

	NATURAL GAS FROM:		
	Abu Maadi Percent	**Abu Quir** Percent	**Abu Ghardig** Percent
Nitrogen	0.385	0.17	0.51 - 0.66
Carbon Dioxide	0.688	0.53	2.83 - 4.00
Methane	92.766	93.85	83.37 - 86.38
Ethane	4.117	1.22	10.18 - 8.13
Propane	1.211	1.22	3.02 - 0.75
Heating Value			
BTU/FT^3, STP	1133.7	1132.6	1132.0
BTU/LB	23056	23238	21427

Source (Research Department, EGPC)

Note that Carlin-Middle East commented that the reported composition of gas from Abu Ghardig does not meet minimum recommended specifications proposed by Detroit Diesel and possibly other US engine manufacturers for heavy duty turbocharged CNG engines. They indicate that the ethane and propane levels are too high. This question, while apparently not now a problem because Abu Ghardig gas is not reaching Cairo, should be investigated further and may have implications for locating or sourcing CNG filling stations in the future. However, most engines can be recalibrated to operate satisfactorily on most gas compositions, although emissions may not be optimum. This is more important in the U.S. with its very strict emission standards. Gas composition is not expected to be a major concern in Egypt.

Under many existing production agreements between Egypt and oil companies, the discovery of gas by an oil company requires Egypt to purchase the oil company's share of the gas or to compensate the oil company for its costs of developing the well. Egypt has four years to begin purchases, at which time the oil company may demand payment and shut down the well if the purchases are not made. Under this system, it is obvious that Egypt has an incentive to install/upgrade transmission and distribution systems in order to purchase gas, so long as the selling price for the gas and the volume of sales projected lead to revenues (in net present value terms) which exceed the costs of the transmission and distribution system upgrades, plus the purchase cost of the gas. Generally, Egypt only has to pay for a fraction of the volume of output from the well, perhaps 20 - 30 percent according to the individual contract, since it claims ownership rights to the remaining gas flow by fulfilling its commitment to purchase the oil company's share. Consequently, given the four year period before the closure/purchase requirements become binding, a rapid increase in gas reserves occurring in the 1992-95 time

frame leads to the need for careful assessment of the best ways to market natural gas, so that economical opportunities for gas use will not be lost in the 1996-99 period.

Production forecasts by the Egyptian General Petroleum Corporation (EGPC) in 1993 appear to be consistent with our understanding of Egypt's contractual agreements with oil and gas producers, indicating a sharp jump in production from 1996 through 2000 (Tawila, Oct. 1993). In the event that a total of 26 trillion cubic feet (TCF) of natural gas reserves can be proved in late 1994 or 1995, EGPC forecasts indicate that natural gas supply will exceed currently projected domestic demand by approximately 1998-2000, and the supply totals will move well above even the high demand projections for sectors now using natural gas.

Although the total 26 TCF has not yet been proved in the summer of 1994, the totals have moved well above the 12 TCF of proved reserves as of October, 1993 (approx. 19-21 TCF), and many anticipate that the 26 TCF total or a nearly equivalent value, will be proved in the next few years. In late 1993, the EGPC, after preparing projections of demand for all sectors now consuming natural gas, estimated that, even with optimistic assumptions, there would not be enough demand from these sectors to take all of the available supply at the turn of the century if a total of about 20 TCF or more were proved. (As noted above, approximately the 20 TCF value of reserves has already been proved: 2nd Quarter, 1994 The Economist Intelligence Unit). Accordingly, the EGPC concluded that development of new markets should be pursued, placing CNG as a transportation fuel at the top of a list of potential new domestic applications of natural gas (Tawila, Oct. 1993).

Exhibit 4.3 depicts the gas production forecast, and Exhibit 4.4 represents the gas supply and demand forecast.

Exhibit 4.3 Gas Production Forecast
(Tawila, 1993)

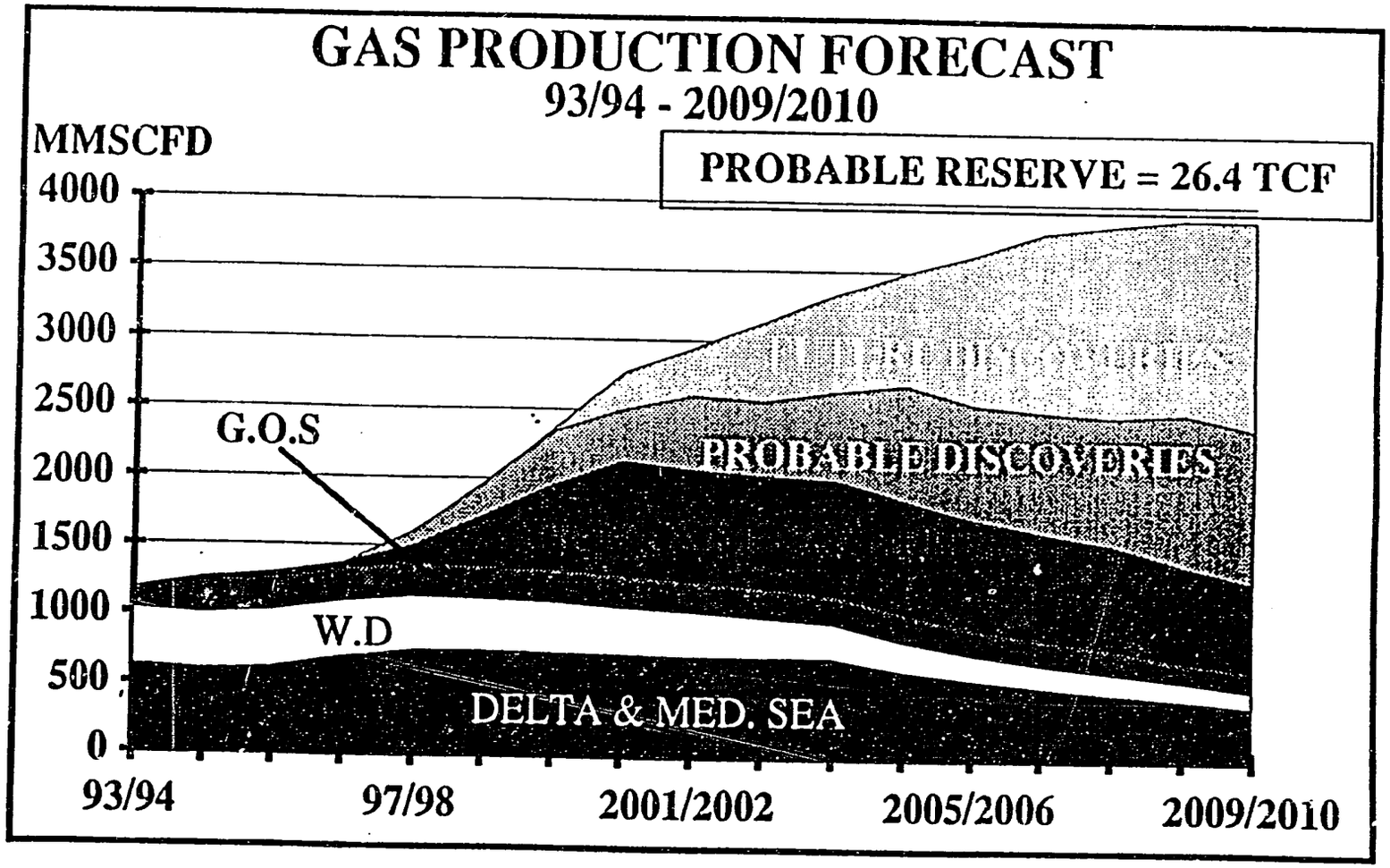
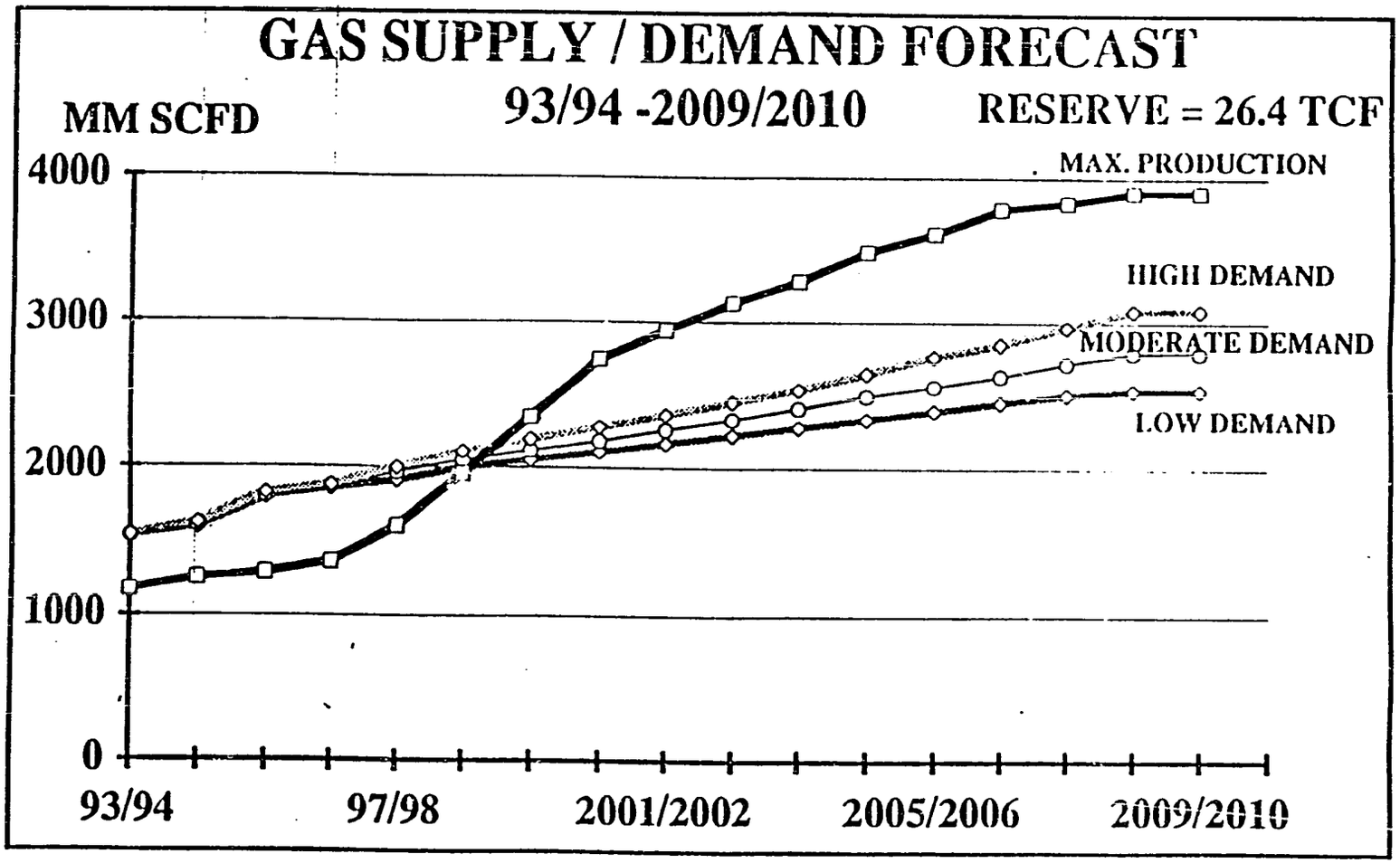


Exhibit 4.4 Gas Supply/Demand Forecast
(Tawila, 1993)



4.3 Pricing Policy

Egypt proved and developed significantly greater oil reserves about two decades ago. The supply of domestically produced oil moved well ahead of the domestic demand for petroleum products, at about the same time that world oil prices moved sharply higher. As a result of these two favorable events, Egypt moved from a deficit in the value of oil exports minus imports in 1975 to a large surplus in 1980. In spite of the fact that the domestic consumption of oil and gas in tonnage terms increased "explosively" from 1975 to 1980 (more than 100 times), and rapidly from 1980 to 1985 (by another 2/3), the net value of Egypt's petroleum sector also increased "explosively", shifting from causing a decrease in Gross Domestic Product (GDP) prior to 1975 to contributing approximately 15 percent of GDP in 1985 (United Nations Environment Program, 1993).

However, in 1986 world crude oil prices collapsed, sharply reducing the dollar value of Egypt's oil exports. In spite of the sharp drop in crude oil prices, the prices of refined products - some of which Egypt imports to balance specific sectoral needs - did not drop so rapidly. Further, the value of the Egyptian pound dropped, making oil product imports more expensive in local currency. Even though demand growth for oil and gas in tonnage terms slowed to 20 percent from 1985-90, the value of imports in dollar terms was reported to have increased by 25 percent (United Nations Environment Program, 1993). The result of the sharp 1985-90 decline in value of crude oil exports and moderate increase in value of imports, combined with growth of the Egyptian economy was a drop of contribution of the petroleum sector to GDP from the 15 percent value in 1985 to about four percent in 1990/91 (United Nations Environment Program, 1993).

As a result of the dramatic increase in oil revenues in the 1980-85 period, it was possible for Egypt to implicitly subsidize domestic petroleum products by selling them to Egyptian customers for prices well below those prevailing in the industrialized nations who are the dominant consumers of oil products. These implicit subsidies, along with the increased wealth provided by expanding oil exports, allowed Egyptians to afford the purchase and operation of a rapidly expanding number of motor vehicles. From 1980 to 1990, it has been reported that the number of motor vehicles in Cairo has increased from about 400,000 to 900,000 (Blackwell, 1992), an annual rate of increase of about 8 percent. Nationwide, from 1981/82 through 1990/94 gasoline consumption increased about six percent per year. The rate of increase of gasoline consumption (and probably of vehicles) was greatest early in the 1980-90 decade, when world oil prices were high and domestic gasoline prices were low. From 1981/82 through 1985/86 gasoline consumption increased by over 10 percent per year, but the rate of increase dropped to less than two percent per year after the collapse in world oil prices and subsequent decline in the rate of growth of the Egyptian economy. Also contributing to the slowing of demand growth for gasoline was a significantly greater absolute increase in gasoline prices than in gasoil or diesel fuel prices from 1985-90 (Abdel-Hakim, Feb. 1993).

The World Bank had ceased lending to Egypt during the 1980s, in large part because of objections to the low domestic prices that were set for petroleum products and natural gas. By the end of the decade, after observing for a few years the combined effects of low world oil

prices on the nation's export revenue, and of implicitly subsidized domestic petroleum product prices on domestic consumption of those products, Egyptian analysts apparently realized that a trend toward decreasing net export revenues from the petroleum sector existed, and the odds were good that this trend would continue under current policy. At the same time the losses in export revenue made the need for loans from the World Bank greater than in the early 1980s. Accordingly, Egypt and the World Bank in 1991 entered into the previously mentioned agreement to raise petroleum product and natural gas prices to world price levels by June of 1995 (World Bank, June 1991).

The consequences of this agreement are likely to be dramatic. In the first place, the agreement recognizes Egypt's history of selling gasoil and diesel fuel for vehicular diesel engines at prices much lower relative to gasoline than in most industrialized nations. In other words gasoil for diesel engines is relatively cheap. As a result, the mix of transportation fuels in Egypt is heavily tilted toward gasoil and away from gasoline. In 1981/82, 46 percent of transportation fuels and lubricants consumption was accounted for by gasoil and 36 percent by gasoline. These shares have been relatively stable, standing at 47 percent and 38 percent in 1990/91.

This mix of fuels has significant implications for the air quality problems experienced in Cairo, as will be discussed later. Similarly, the agreement with the World Bank - which requires a sharp increase in the price of gasoil and diesel fuel but not gasoline - has implications concerning the direction of change of transport sector fuel consumption and emissions. In particular, the likely change in price structure will encourage a shift away from diesel engines and toward gasoline engines in motor vehicles purchased after 1995. This is also an important consideration with respect to conversions of vehicles to natural gas, because it is somewhat less expensive to convert gasoline engines to natural gas than to convert diesel engines.

A recent study by Adel-Hakim for USAID estimated world prices for various petroleum products and natural gas. Selected numbers from that study are presented below. Note that, according to that study, the 1992/93 Egyptian domestic price ratio for gasoil relative to regular gasoline was 0.30, while the estimated world price expressed in Egyptian pounds led to an estimate of a ratio of 1.01. Note that the 1992/93 price of gasoil would have had to rise by 131 percent to reach world levels, and the 1992/93 difference in gasoil and natural gas price would have jumped from 226 LE/ton to 566 LE/ton. Obviously, the absolute fuel savings from substituting natural gas for gasoil would jump sharply if these estimated price adjustments were made.

Exhibit 4.5 Past Egyptian and Recent World Prices for Key Petroleum Products and Natural Gas

Fuel	Egyptian LE/Ton 86/87	Egyptian LE/Ton 89/90	Egyptian LE/Ton 92/93	World LE/Ton 92/93
Premium Gasoline	350	559	1295	898
Regular Gasoline	280	490	1257	860
Gasoil (Solar)	36	81	378	872
Diesel Fuel	30	75	132	872
Fuel Oil	15	35	115	306
Natural Gas	15	35	152	306

Source (Abdel-Hakim, Feb. 1993)

The above table makes several facts apparent. First, the agreement will have little effect on those customers who would otherwise intend to purchase and use a gasoline vehicle. Second, the agreement will have a dramatic effect on customers who would otherwise purchase a diesel engine powered vehicle. Those consumers who will not under any circumstances consider switching to a gasoline for a diesel fueled vehicle would nevertheless be likely to carefully evaluate any replacement of diesel engines, and would be far more likely to purchase an advanced, more efficient diesel engine. Many current diesel engine users will also be likely to consider whether they should switch from gasoil to gasoline or natural gas. A third effect of the agreement will be to slightly reduce the chances of converting gasoline powered vehicles to natural gas, switching to natural gas when replacing a gasoline vehicle, or purchasing a natural gas vehicle rather than a gasoline vehicle when making a first purchase. If the Egyptian government had chosen to drop gasoline prices to the world level and increase natural gas to the world level in 1992/93, the difference in price between gasoline and natural gas would have dropped from 1105 LE/ton to 554 LE/ton. However, a fourth effect is opposite to this one, providing a greater incentive to switch from gasoil to natural gas, where the difference rises from the previously noted values of 226 LE/ton to 566 LE/ton.

Note that in commenting on the draft of this feasibility study, the Organization for Energy Planning provided some slightly revised figures for the prices of fuels in Egypt from 1986 through 1993. The table they provided is shown in an Appendix to this report. The differences in the values are not significant enough to change the findings or conclusions presented in this discussion. An extensive review of the validity of the data from the two sources was not deemed warranted for the purposes of this study. Future prices are of more concern.

One source (among many) of uncertainty about the future prices of gasoline, gasoil and diesel fuel is the flexibility of the agreement with the World Bank. The agreement requires that the average price for petroleum products rise to world levels, not that any single price exactly match world levels. Further complications arise with respect to the point at which the world prices are established and the quality of the fuel to which the Egyptian petroleum products are compared.

Although the degree of incentive per ton of oil equivalent for switching to natural gas is less for gasoil than gasoline, gasoil-fueled vehicles are generally more heavily utilized than are gasoline fueled vehicles, leading to opportunities to realize similar or greater annual savings owing to the offsetting effect of greater annual fuel consumption and more rapid recovery of savings.

There is inherent flexibility in the World Bank/Egypt agreement concerning the matching of bulk natural gas prices to international fuel oil prices. International fuel oil is not a single commodity. Its price can vary widely, dependent on fuel composition - primarily indicated by sulfur content (though sulfur content does tend to be associated with other properties). In the study "Natural Gas Pricing in Egypt," by D. Hertzmark, the Oct. 1993 "international" price of fuel oil with 3.5 percent sulfur content is listed as $55/tonne, while the price of fuel oil with one percent sulfur content is listed as varying from $85-90/t, "65-70 percent of crude oil prices" in a footnote, and as $92/tonne in the table with the $55/tonne value for the 3.5 percent weight sulfur crude oil (Hertzmark, Nov. 1993, p. 15). The footnote implies oil prices in the $121-138/tonne range. Thus, the quoted price of high sulfur fuel oil is in the neighborhood of 40-45 percent of the crude oil price. In the event that natural gas prices were pegged to the international price of high sulfur fuel oil, the gas price in Table 1 could be as low as $70/tonne (233 LE/tonne), well below the illustrated value.

According to the numbers for natural gas in Tables 2.1, 2.2, and in Annex 2 of the Hertzmark study (not duplicated in this report), a $70/tonne of crude oil equivalent price of natural gas would be about two dollars per million BTU's ($2/10^6$ BTU's), a price sufficient to cover costs of production and delivery to Cairo of bulk gas in nearly all circumstances evaluated. Hertzmark's Annex 2 indicated that Egypt's bulk gas costs should range from about $1-2 per million BTU's, with lowest costs for field extensions (Hertzmark, Nov. 1993).

4.4 Natural Gas Distribution System

The natural gas distribution network is growing rapidly in Cairo as the Ministry of Petroleum seeks to expand the use of gas in all sectors. A diagram illustrating the main distribution lines of the natural gas distribution system is provided in Section 6. Currently, a 7 bar line runs up the western side of the Nile. There are now about four crossings of the line under the Nile to serve the other side. A large 30 bar line runs up the western side of the city. EGPC plans on a number of lines that will extend from this line west-to-east across the city. EGPC has indicated that they are very interested in cooperating with any CNG conversion program and will extend lines as necessary to meet the need.

The position of the public bus terminals relative to the gas distribution line and the costs for extending and connecting to the line are discussed later as inputs to the economic analysis.

4.5 Gasoil/Diesel Supply

Because CNG will substitute for gasoil/diesel fuel in the transportation sector, a brief summary of the status of supply and consumption of this fuel in Egypt is provided in the tables below.

Exhibit 4.6 **Gasoil/Diesel Production Imports and Consumption in the Year 1992/93 (Thousand Tonnes)**

Item	Quantity
Gasoil/Diesel Production	4569
Gasoil Imports	335
TOTAL	4905
Bunker	-300
Gasoil/Diesel Available for Domestic Consumption	4604

Exhibit 4.7 **Sectoral Consumption of Gasoil/Diesel in 1992/1993 (Thousand Tonnes)**

Sectors	Quantity	Percentage
Transport	2977	64
-Public	558	12
-Private	2419	52
Electricity	115	2.5
Other	1560	33.5
TOTAL	4652	100

"Other" includes industry, housing, agriculture, petroleum, and investment.

Section 5.0 Selected Issues

5.1 Safety

The study team encountered significant concern about the safety of CNG vehicles and storage facilities in Egypt. Frequently, the technology is seen as similar to the butagas cylinders used in homes and which have been responsible for a number of very violent explosions and deaths in Cairo. These failures have been attributed to poor manufacturing quality control as a number of local manufacturers have introduced poor quality versions of the simple sheet metal cylinders in to the local market. The poor ones are visually indistinguishable from the good ones.

It is important to recognize the differences between the very substantial cylinders used in CNG and the light-weight tanks used for butagas. Also, the properties of the fuels themselves are quite different relative to explosion potential.

We recommend that Egypt adopt a range of standards, regulations, and procedures similar to those in the U.S. that have resulted in a very good record of CNG vehicle safety in the U.S. New cylinders are manufactured, tested, and certified in accordance with U.S. Department of Transportation (DOT) regulations, Transport Canada (TC) regulations, or American National Standards Institute (ANSI)/A.G.A. NGV2 standards. All cylinders must be periodically recertified. Steel cylinders must be recertified every five years, and steel-composite and aluminum-composite cylinders must be recertified every three years. Cylinders manufactures to ANSI/A.G.A. NGV2 specifications have a 15-year useful life, and no requirement for recertification.

Currently, the recertification procedure for DOT or TC cylinders requires that the cylinders be removed from vehicles and taken to a DOT-approved facility. Cylinders are recertified by hydrostatically testing them to ensure they maintain pressure and have no leaks or stress cracks.

Natural gas onboard cylinders are manufactured to strict industrial standards using sturdy material. These cylinders are considered much safer than those used to hold liquid fuels, which are made of thin sheet metal. Natural gas cylinders are tested to 5,000 psi pressure, and are designed to withstand 7,500 psi. One out of every 200 cylinders is subjected to a cyclic pressure test. This test includes cycling (filling and recharging) the cylinder 25,000 times at extreme temperatures.

Compared with gasoline and diesel vehicles, natural gas vehicles have proven to be very safe. Because natural gas is a vapor and not a liquid, it has unique characteristics. Unlike liquid fuels which pool on the ground when leaked or spilled, natural gas is lighter than air and will dissipate into the atmosphere if leaked. The ignition temperature of natural gas is 1,200 degrees F, compared to 600 degrees F for gasoline, which makes it more difficult to ignite. Natural gas will burn only when the proper air-to-fuel ratio exists. Therefore, natural gas will not burn in concentrations in air below 5 percent or above 15 percent.

Severe abuse tests have been conducted that included shooting cylinders with bullets, burning in a fire, and dynamite detonation. In each case, there were no ruptures of the cylinders or fuel ignition.

Fueling of natural gas vehicles is also a safe process. Natural gas is dispensed through sealed systems that are designed to allow natural gas to flow into the vehicle without leakage to the atmosphere. In dispensers using ANSI/NGV1 nozzles, unless the nozzle is properly connected to a receptacle on the vehicle, natural gas will not flow. All natural gas fueling stations built in the U.S. comply with National Fire Protection Association (NFPA) standards for safety. These standards include comprehensive, stringent construction specifications. In the U.S., the following organizations have developed standards and codes to ensure both the safe construction and operation of natural gas fueling stations. These standards are not directly transferable to Egypt. They are offered here to indicate the range of standards required and as a reference for Egypt's own CNG standards development process.

ASME (American Society of Mechanical Engineers)

- Boiler and Pressure Vessel (B&PV) Code, 1986 Edition, 1987 Addenda.
  - Section VIII, Division I - Pressure Vessels
  - Section V - Nondestructive Examination
  - Section IX - Welding & Brazing Qualifications
- ASME/ANSI B31.3 - Chemical Plant and Petroleum Refinery Piping, American National Standard, 1984 Edition

ASNT (American Society foe Nondestructive Testing)

- ASNT-TC-IA Recommended Practice

AWS (American Welding Society)

- DI.I-88 Structural Welding Code - Steel

NEMA (National Electrical Manufacturers Association)

- Standards

NFPA 52 (National Fire Protection Association)

- NFPA 52 - 1993, Compressed Natural Gas vehicular Fuel Systems
- NFPA 70 - 1987, National Electric Code

DOT (Department of Transportation)

- Specification 49 CFR, Sections 172, 178, 393 - Latest Edition

OSHA (Occupational Safety and Health Act)

- Title 8, Article 7 of the Administrative Division on Industry General Safety Orders

UBC (Uniform Building Codes)

- 1988 Edition, Local jurisdiction

UL (Underwriters Laboratory)

- Approval

In Egypt, Egypt Gas is responsible for the natural gas distribution lines. According to Law No: 217, Egypt Gas is also charged with establishing procedures for testing CNG cylinders and for certifying CNG cylinders that pass the test. A full range of additional codes and standards as described for the U.S. situation is required in Egypt to ensure the safe operation of the CNG fleet. (Much of the material on safety issues presented here was taken from a Columbia Gas

1994 informational guide to natural gas vehicles.)

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5.2 Power/Torque Loss

Power/torque loss always occurs when a naturally aspirated gasoline (spark ignited) engine is converted to natural gas. This is also true for dual-fuel conversions of naturally aspirated diesel engines. By careful selection of a turbocharger, there is no power loss associated with conversion of a turbocharged diesel to dedicated natural gas engine. Engines in Cairo are predominantly naturally aspirated.

It is theoretically, and sometimes practically, feasible to modify a naturally aspirated gasoline or diesel engine to operate as a turbocharged natural gas engine with zero power loss, or possibly some power gain. Costs of such modifications will be higher (versus no turbocharger) and older engines may not be suitable for such modifications.

Within this study, the case which is of most concern, relative to power loss, is the CTA buses. The economics of dual fuel conversion of these buses are evaluated in Section 7. The manager of the CTA fleet has serious reservations about the acceptability of any power or torque reduction in his bus engines. It is his belief that these engines are operating marginally now relative to the demands placed on them and that reduction in torque would be unacceptable. Because these engines have never been modified to CNG before, the dual fuel option would require more careful testing during the pilot phase, given these concerns. The study team's review of the case concluded preliminarily that the engines used are adequately sized relative to their load to accept a slight reduction in power (10 to 20 percent.) However, the study team considers the dedicated natural gas engines to be the more "technically certain" option, which would avoid the question of power loss.

5.3 Compression Ratio Impacts

The Statement of Work for this study requested that the issue of Compression Ratio be addressed. This subject has been discussed in various sections of the report but is reviewed briefly here for clarity.

Compression Ratio (CR) is the ratio of the volume in an engine cylinder at the piston's furthest point (largest volume, lowest compression) in the stroke to the volume of the cylinder at highest compression (smallest volume). Engines are designed with different CR's to account for the characteristics of the specific fuel intended to be used. The selection of a given engine's CR in the design process is essentially a compromise to achieve the best mix of power, low emissions, and efficiency. Thus, when an engine that was originally designed for either gasoline or diesel fuel is made to run on CNG (or any other fuel,) the power, emissions, or efficiency are not the same as with the original fuel. For this reason, the compression ratio is an important engineering consideration.

Most gasoline engines are designed with a CR of between 8:1 to 10:1. Most diesel engines are designed with a CR of between 14:1 to 18:1. The optimum CR for a CNG engine is about

11:1. Natural gas will not autoignite under compression, so either a spark plug or a small amount of diesel to act as a pilot ignition sources needed.

Therefore, unless a CNG conversion in an engine includes a modification of the cylinders, stroke, or head to change the CR from the original engine specification, the engine will not be optimized for power, emissions, or efficient combustion of the natural gas.

Gasoline or diesel engines can run on CNG without changes in their CR, but their performance suffers. As a result, add-on kits that only change the fuel introduced into the cylinders lose performance relative to the gasoline or diesel operation for which they were designed. Their power is lower and they are not as efficient. The emissions of some pollutants may be lower than with the original fuel, but the emissions of other pollutants may be higher. These non-optimum characteristics are frequently accepted due to the lower cost of this type of conversion, if the operational requirements of the vehicle can be met with the lower power.

Engines that are modified to run on two fuels simultaneously or switched from one to the other cannot be optimized for both. Hence, naturally aspirated bi-fuel and dual fuel engines have poorer power, emissions, and efficiency relative to dedicated CNG engines with modified CR. For this reason, whenever possible, engineers prefer to make changes in the engine CR and use dedicated CNG engines.

For the purposes of this study, the CR is assumed to remain unchanged for dual fuel and bi-fuel applications. The corresponding decreases in power and efficiency are discussed elsewhere in this report. When new, dedicated CNG engines are discussed, they are assumed to have CR's optimized for CNG.

5.4 Egyptian Manufacturing/Assembly Capability

Egyptian industry currently manufactures numerous automotive components and assembles passenger cars, buses, and other vehicles. Certainly, Egypt has the capability of manufacturing a significant portion of the components used in CNG engines, as well as the engines themselves. However, the engineering and tooling up to produce these components represents a significant investment that should probably be held until the future direction of CNG use is determined in this country. When it has been determined that CNG vehicles are acceptable, the logical next step will be the manufacture or assembly of new or reconditioned natural gas engines in Egypt. For this task, the public and private sector companies that may be candidates are: The El-Nasr Automotive Manufacturing Company (NASCO), CTA, GCBC representing the public sector; or Carlin Middle East, Ghabor, Isuzu, Ghorica, representing the private sector. General Motors (GM) is another manufacturer in Egypt, but they have not yet expressed an interest in applying the technology in Egypt.

As for production of the CNG cylinders, one military manufacturing company is believed to have the capability of producing them due to their experience in production of high pressure chlorine gas storage cylinders. A broad CNG conversion program should include measures to encourage Egyptian firms to enter the arena. Benefits in the form of higher employment and

better balance of trade would accrue to the Egyptian economy as a result. The program must rely in its early stages on foreign equipment: engines, conversion kits, cylinders, compressors and controls. Assembly and installation of components is certainly within the current capability of Egyptian firms.

The economic analysis presented in Section 7 makes assumptions regarding the percentage of local contribution to the costs of the system as listed in Exhibit 5.1.

Exhibit 5.1. Assumed Import/Export Fractions Used in Economic Analysis

CNG System Component	Percent Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
Vehicle Conversion Kits	100
Vehicle Tanks	100

5.5 CNG Project Development

As mentioned elsewhere in this report, for many years vehicles have been converted to operate on CNG. The technology exists and is relatively well developed. However, each application is different and the conversion to CNG can have significant negative impacts on the performance of the vehicle. It must also be remembered that there have been failures in CNG conversions. Generally, problems that are encountered in a conversion can be resolved with technical fixes if basic errors have not been made in the selection of the specific conversion methods chosen for each vehicle. It is also worth repeating that the specific engines in the CTA bus fleet, for instance, have not been converted to CNG before, although efforts are underway.

In light of these factors, **any recommendation or further consideration in this report of CNG conversions of major fleets in Cairo assumes that, in the event that a decision is made to proceed with a conversion program, a significant engineering phase and a pilot program phase will be included.** We assume that at least a one year engineering phase will be undertaken before a significant number of vehicles are converted. This phase would include extensive review of available conversion kits or engines for appropriateness of application, selection and design of storage systems, and careful engineering of concepts discussed in this report. It would also include engineering and emissions tests in a typical CTA diesel engine appropriately modified to operate as a dual fuel or dedicated engine. Engine dynamometer tests must be conducted to determine the BHP, torque, and fuel consumption characteristics at different loads and speeds. The data will be compared with the standard diesel engine. Costs of conversion kits and time needed for conversion must be documented. This engineering

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development activity must be an integral part of the conversion program, and professionals from the appropriate fleets and the appropriate agencies of the Ministry of Petroleum should participate.

The engineering phase must be followed by a pilot phase in which the designed conversions are implemented in a few vehicles. **Some problems should be expected with the first vehicles converted.** It is important that these problems be identified and corrected before proceeding to full scale conversion of the fleet(s). We recommend that a one year pilot phase be included in the overall program, depending on the technology options selected. Existing CNG engines already in use elsewhere might require only a one year program, while entirely new, unproven engines or conversions might require two years or more.

5.6 Extended Engine Life and Reduced Maintenance Costs

Some proponents of CNG use as a transportation fuel claim that CNG use can extend the useful lifetime of an engine and that this represents a significant cost savings. The study team does not believe that this claim has been sufficiently demonstrated. In addition, one must remember that gasoline engine vehicles in Cairo are operated for a very long time anyway (about 20 years). A significantly longer engine life would be very difficult to demonstrate here and of questionable present value in a 15 year economic analysis using interest rates of 10 percent or so. Diesel engines in the bus fleets are replaced and rebuilt more frequently. In these applications, CNG engines have the best chance of extending engine life, but until a pilot phase demonstrates extended life, we recommend that feasibility decisions not be based on assumed increases in engine lifetime.

Reduced maintenance costs are also claimed in conjunction with the longer engine life. The study team believes that reductions in the maintenance costs, especially in the early stages of an unfamiliar technology, cannot be counted on. It is uncertain as to how much a particular type of fuel affects the maintenance requirements of a Cairo vehicle, especially in light of the questionable routine maintenance some vehicles receive and the very high levels of air-borne particulate that can get into an engine. For these reasons, we have not included any adjustments for decreased maintenance or extended engine life for CNG vehicles in the economic analysis.

5.7 Reduced Lubricating Oil Consumption

Advocates of CNG vehicles also point to the ability to increase the time between oil changes because of the cleaner burning characteristics of the fuel. However, the dusty air in Cairo may be a bigger factor in oil contamination than blow-by of fuel combustion products. Also, the high cost of vehicles in Cairo relative to personal income and the historically low cost of oil has led to an oft-cited habit of changing engine oil very frequently under the belief that this would extend engine life. It may be difficult to get the users of CNG vehicles to take the chance on extending their oil change schedules. To some degree, with the lack of experience and test data in Cairo applications, caution is probably best. Thus, we have not included any reduction in engine lubricating oil costs in the economic analysis.

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Section 6.0 Selection and Description of Options for Detailed Study

6.1 Rationale for Selection

As described in Section 4, the vehicle population in Cairo is large and diverse. Given the task of defining where early efforts should be made to convert the vehicle population to CNG, we elected to use several subjective screening criteria to reduce the extent of the analyses to reasonable levels. Some "conventional wisdom" or rules-of-thumb have developed for CNG conversions and a few are worth repeating here. These are not hard-and-fast rules, only guidelines.

- Small passenger cars are generally more difficult to convert than larger vehicles due to reduced space available for cylinders and they are more difficult to economically justify converting due to higher fuel economy, which reduces the cost savings potential of CNG.

- Fuel injected and electronic ignition vehicles generally perform more reliably when converted than vehicles with carburetors and mechanical ignitions.

- The greater the number of engine types within a given population, the greater the engineering effort associated with the conversions. Each engine type requires a specialized "kit" and some engineering to optimize.

- An old vehicle in poor condition may not have enough useful life left to justify a conversion.

- Vehicles operated in fleets with central ownership, central maintenance, and that return daily to a central location offer significant advantages in terms of economies of scale and the greater degree of control that can be exercised over such fleets during an early conversion program. This is not to say that other fleets should not be considered. Rather, in the opinion of the study team, "true fleet" operation as defined above offers a more controllable place to begin. Of the parameters that define a fleet and impact the likelihood of success of a conversion effort, we see central ownership and central maintenance as more important than returning to a central location. In addition, a lower level of diversity of vehicle and engine types in the fleet is advantageous.

- New dedicated CNG engines are more "technically certain" conversions than dual fuel or bi-fuel retrofits.

Some of the above do not offer much help in selecting among the options in Cairo. There are very few vehicles with electronic injection and controls in the Cairo area because of the high average age of the vehicles and higher cost of electronic control systems. In addition, the growth in the number of many types of vehicles is such that only using CNG in new vehicles would take too long to have an impact. For instance, annual new bus purchases for the CTA bus fleet are

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less than five percent of the fleet.

Several other factors should be considered in the selection process:

- USAID's interest in CNG conversions is largely driven, at this time, by concern with the poor air quality in Cairo. Vehicles that operate a significant portion of the time outside Cairo would have little impact on Cairo Air Quality if converted to CNG.

- Air-borne particulate is well known to be a major problem in Cairo. Diesel engines typically produce many more times the quantity of particulate matter than gasoline vehicles.

- The fleet selected should be significant enough to have an "impact." Included in this term is the degree to which a selected portion of the fleet could act as a "seed" or example for later CNG conversions. Also included is impact on natural gas utilization and emissions reductions.

Given all these criteria, let us review the Cairo vehicle population. Refer to Section 4.1 for quantitative data.

- **Passenger cars** - The car population in Cairo is large and growing, and certainly is tempting to target for CNG conversion. Almost all passenger cars have gasoline engines. However, the age of the average car, the great diversity of engine type, the small size of and the poor maintenance given the typical car, and the high passenger loads frequently encountered with small engines all combine to make them an unlikely early target. We could identify no automobile fleets that are operated as true fleets, including taxis. Taxis are individually owned and operated for the most part. Most government vehicles are operated no differently than personal passenger cars. One exception may be the passenger cars used by the electric authority residential area service personnel, but we were not able to get adequate information on them in the time available.

- **Buses** - The bus population is made up of school buses, tourist buses, public buses, and private buses. Almost all buses have diesel engines. School buses are generally operated in very small fleets by private schools. They are of very diverse engine type, age, and condition. They are dispersed throughout the area and do not operate year-round. They would thus be poor candidates for early application of CNG. The tourist buses must be able to be used on long trips outside Cairo and the tourism industry is still economically depressed. Therefore, until the CNG distribution network is greatly extended, early conversion efforts should probably not focus on tourist buses. Several significant fleets can be found in the remaining categories of buses. Many of the large public companies have large bus fleets to pick up their employees. These fleets are housed within a central company facility and make several rounds each day depending on the

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number of shifts operating at the plant. Two large bus fleets, the Cairo Transit Authority (CTA) and the Greater Cairo Bus Company (GCBC) operate many buses for public transportation. Both of these latter bus fleets have justifiably been the subject of interest for CNG conversion for some time. As a result of this interest and because of the real advantages offered by these opportunities, this feasibility study must address the public transportation bus fleet.

The microbus or minivan taxi fleet has been growing very rapidly in Cairo. These microbuses are individually operated. They are usually very crowded and travel significant distances each day. Their small size and high loading make them unlikely candidates for early conversion. However, the growth rate in this type of vehicle does make the analysis of new dedicated CNG vehicles of interest. Insufficient data were available for analysis of this option.

- **Trucks** - The number of heavy duty trucks greatly exceeds the number of buses in the Cairo area by a factor of about 9:1. Almost all of the heavy duty trucks have diesel engines. It is very difficult to get accurate data on the make-up of the truck population. Apparently, many are owned and operated by individuals. Many of the trucks are long haul trucks or construction related vehicles that must be able to operate outside the Cairo area. However, we did identify several delivery truck fleets that are operated in true fleets and that may offer significant opportunities for early CNG applications. For instance, the Cairo Beverage and Industrial Company (7-Up) operates a fleet of about 200 delivery trucks that make several rounds a day. The company has expressed a strong interest in CNG for its vehicles and also for the forklifts used in the plant. The Coca Cola distributor was also visited and has a similar fleet. No information could be obtained on light duty trucks. Many are known to operate on gasoline. Some of the ministries have fairly large numbers of trucks.

The strategy selected was to pick several specific cases from each of the general vehicle types and perform sensitivity studies around them to permit planners evaluating other cases to draw inferences from this study. (We recommend, however, that detailed investigations be conducted before any actual conversions are done on any vehicle.)

Passenger cars were included in the analysis because of their number and growth rate. Heavy duty trucks are important because they probably represent the largest fuel consumer of the transportation sector. Buses were included because the nature of their operation makes them very good candidates.

In each case, various individuals have been proponents of different approaches to the conversions. For instance, some people in authority believe dual fuel conversions are best; others feel that bi-fuel is required; still others advocate dedicated engines. Given this situation, it is best to evaluate the economic feasibility of each type of conversion to facilitate development of a consensus. This multi-case approach is also the best way of providing sufficient information to assess the overall potential of CNG as an alternative fuel for the Cairo area.

Based on all the foregoing considerations and others, the following options were selected for more detailed analysis:

- **The CTA Bus Fleet**
  - Dual fuel retrofit conversions
  - Dedicated CNG retrofit conversions
  - New dedicated CNG engines
  - New dedicated CNG buses
  - Dual fuel, closed loop controlled retrofit conversions

- **The Cairo Beverage and Industrial Company Truck Fleet**
  - Dual fuel retrofit conversions
  - Dedicated CNG retrofit conversions
  - New dedicated CNG engines
  - New dedicated CNG trucks

- **A "Typical" Passenger Car Fleet**
  - Bi-fuel retrofit conversions
  - New dedicated CNG automobiles

- **Light Duty Gasoline-fueled (Pickup) Trucks**
  - Bi-fuel retrofit conversions
  - New dedicated CNG trucks

We provide in the next subsection a brief description of the assumptions made and some of the engineering details that are used in each case in the economic analysis of Section 7.

6.2. Input Values for Modeled Options

There are two bus companies that serve the city transportation needs within Cairo. These are the Cairo Transit Authority (CTA) and the Greater Cairo Bus Company (GCBC). The following tables give details of the number of garages associated with each company and the types of vehicles that each company operates.

Exhibit 6.1 Cairo Public Bus Fleet
Cairo Transit Authority & The Greater Cairo Bus Company

Bus Age in Years	0-5	5-12	12-16	>16	
CTA Garages	**NASR 871**	**NASR 811**	**Heavy Duty**	**Mercedes**	**TOTAL**
Terra	10	131	64	--	205
Mezalat	15	132	42	--	189
Sawah	135	--	--	--	135
Gesr El Suez	17	222	8	--	247
Amiria	62	94	39	--	195
Nasr	83	150	7	--	240
Fath	10	159	7	--	211
Atr El Nabi	20	168	28	--	216
Fom El Khaleg	10	29	61	--	100
Giza	21	35	22	--	78
Mounib	119	--	--	87	206
Imbaba	114	--	--	107	221
Badr	--	140	--	--	140
TOTAL	616	1260	313	194	2383

Notes:
1. The Heavy Duty Bus has a water cooled DEUTZ engine Model FB 413L
2. The Nasr Bus 811 has an air cooled DEUTZ engine Model FBL 413
3. The Nasr Bus Model 871 has IVECO engine Model AP 160
4. The Mercedes Bus has engine Model OM 352.

(Hamid Mokhtar, Abdel, Head of Technical Affairs, CTA, MAY 1994)

Exhibit 6.2 Greater Cairo Bus Company -- Status of Existing Buses

	Status of Existing Buses		
Branches	Total	Under Repair	In Operation
Helwan	214	32	182
Cairo	130	3	127
Katamia	210	5	205
Port Said	249	40	209
TOTAL	803	80	723

Note: The IVECO buses at GCBC are fitted with Fiat 8210.02 engines.
(Abas Nadim, Eng. Shehata, General Technical Manager, Greater Cairo Bus Company, May 1994.)

Exhibit 6.3 CTA and GCBC Buses in Cairo

	Cairo Buses		Total
	Operational	Repairs	
CTA	2271	524	2795
GCBC	723	80	803
TOTAL	2994	604	3598

Cairo Transit Authority (CTA) has 13 garages with a total of 2383 buses. There are 616 Nasr 871 fitted with IVECO Model 160 diesel engine, 1260 Nasr 811 with DEUTZ air cooled engine Model 413 , 313 Heavy Duty DEUTZ water cooled engine Model 413 L and 194 Mercedes Benz engine Model OM 352. For the economic analysis, it was assumed that the average number of buses per CTA garage is 220.

The distance travelled by the CTA buses is 230 KM per day. The distance travelled ranges from 170 KM /day to 370 KM/day.

Exhibit 6.4 Status of CTA Vehicles

CATEGORIES	STATUS OF CTA BUSES	
	In Operation	Out of Service
NASR Buses in Service	2047	--
NASR Buses to be Scrapped	--	76
NASR Buses Under Repair	--	328
Iranian Mercedes Buses in Service	234	--
Iranian Mercedes Buses to be Scrapped	--	53
Mercedes Buses Under Repair	--	67
TOTAL	2271	524

Note: The total number of CTA buses according to the breakdown (2271 + 524) in Table 1 is less than the total CTA buses (2383) reported in Table 3. This might be due to the Iranian Mercedes minibuses not reported in the breakdown in Table 3.

(Hamid Mokhtar, Mr. Abdel, Head of Technical Affairs, CTA, May 1994)

Of the 2047 Nasr buses available for service (Refer Exhibit 6.4), 80 percent are scheduled for light operation each day. Of this number, 90 percent operate 16 hours per day and remaining operate at 8 Hours per day.

Storage Cylinders on Board the Buses.

The equivalence between the BTU content of natural gas and diesel fuel is computed as follows: The heating value of 136 Standard cubic feet (SCF) of natural gas is equivalent to the BTU content of one U.S. gallon of diesel oil.

Using the weighted average of 56.56 liters of diesel oil consumed by the heavy duty CTA buses travelling a distance of 100 km, the fuel consumption for 270 km = 152.71 liters of diesel oil.

The equivalent amount of natural gas for 270 km is 5487 SCF.

Assuming that the diesel and converted natural gas engines have efficiencies of 36 percent and 32 percent respectively, the natural gas equivalent for the converted CTA bus, allowing for differences in engine efficiencies, will be 6173 SCF.

The ratio of the estimated SCF volume at standard pressure to the inside volume (in^3) of a cylinder at 3000 psi is 0.172 SCF / in^3.

The inside volume for the storage cylinder = 35890 in^3

Choose a filament wound aluminum/ E Glass design cylinder 11.3" in diameter and 72 " long weighing 130 pounds. The inside volume of the cylinder = 5218 in^3.

The average number of cylinders = 35890 / 5218 = 6.88 cylinders.

Choose 8 cylinders with a volume of 41744 in^3. The reserves will be 41744 - 35890 / 35890 = 16.4 percent.

For the case of the dual fuel, both open and closed loop controlled, conversion of diesel engines, part of the fuel (10 - 15 percent) will be supplied by diesel fuel. This fact provides additional reserves of natural gas.

In the case of dedicated natural gas engines, the entire fuel will have to be supplied by natural gas. For this case 10 cylinders were selected for the analysis.

Even though the economic and financial analyses call for the entire bus fleet, the analysis and pilot study of typical buses within the CTA fleet will provide adequate insights to the operation of all the CTA and GCBC buses because both companies operate similar buses. Further, the team did not find equivalent detail of engineering and cost data on the GCBC garages and buses.

The economic and financial analyses of CNG conversions relate to the water cooled Nasr 871 and the air cooled Nasr 811. Two separate CTA garages were selected because each garage has a predominant number of Nasr 811 or Nasr 871 buses at each garage as indicated below:

6.2.1 Number of Buses

Pilot Garage	Nasr 871	Nasr 811
1. Gesr El Suez	17	222
2. Amiria & Sawah	197	94

The buses at Gesr El Suez can be tested for the conversion of air cooled Nasr 811 engines to CNG while the garages at Amira & Sawah are targeted as a group to test the conversion of water cooled Nasr 871 engines to operate on natural gas. Thus the garage at Gesr El Nasr will be serviced by one natural gas filling station located at the garage while the garages at Amiria & Sawah will share one natural gas filling station.

The three garages are located on the eastern side of the Nile river as indicated in the following map (Exhibit 6.8). On the eastern side, natural gas main lines with a pressure of 30 bar are available. Each station selected for the pilot study is located near the 30 bar line, thus the cost of the natural gas pipeline extension to the garages will be low relative to other locations.

Even though there will be four crossings of the natural gas pipelines across the Nile river, for the time being the available line pressure on the western side of the Nile river is at 7 bar.

The average fuel consumption for the different types of CTA buses is given in the following table.

Exhibit 6.7 Fuel Consumption for CTA Buses

TYPES	Diesel (Solar) Fuel: liters/100 km	Engine Oil: kg/100 km
Heavy Duty	56.0	1.0
NASR 811	56.0	1.1
NASR 871	58.0	0.7
Mercedes	42.5	0.9

Notes:

1. The average distance traveled by new buses before the first overhaul: 414300 KM.
2. After the first complete bus overhaul, the engines are overhauled each time the average additional distance travelled is 70,000 KM
3. The number of revenue passengers per heavy duty CTA bus/day in 1994 was 1198
4. The number of heavy duty CTA buses in operation = 2000
5. The average distance travelled by CTA bus = 230 KM/day

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Exhibit 6.8 Map of the Garages

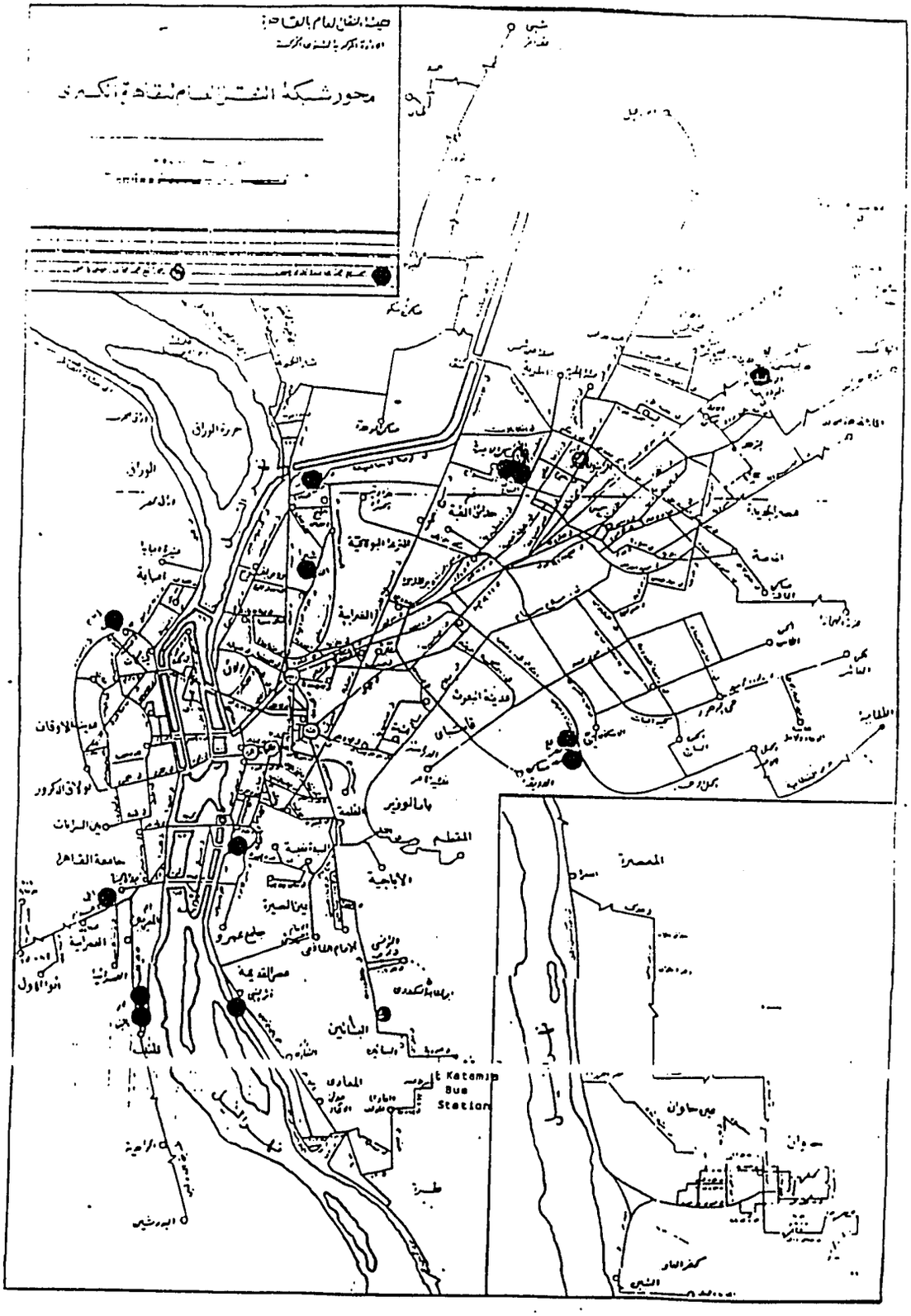
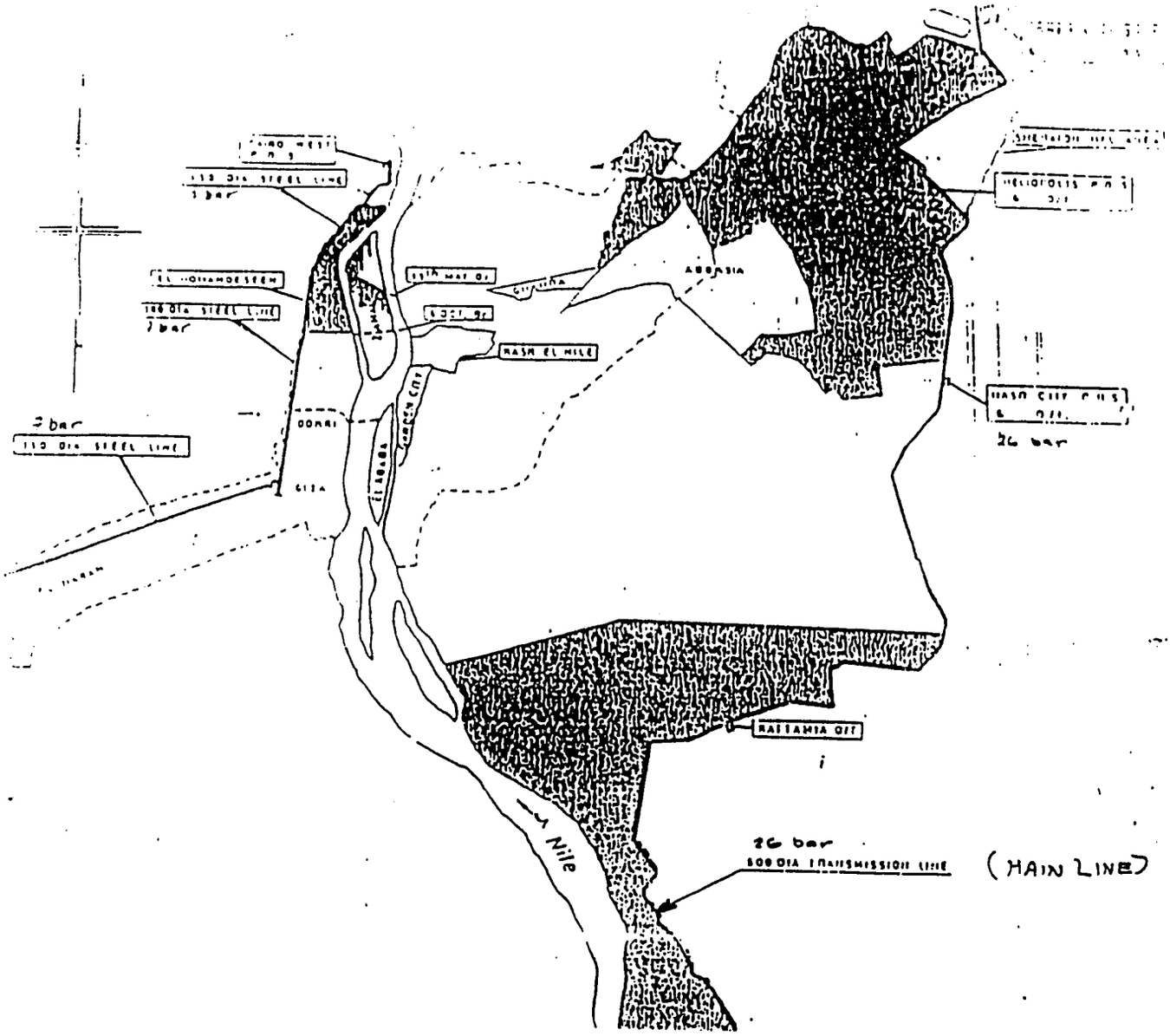


Exhibit 6.9 Distribution System



Of the 2047 Nasr buses available for service at CTA, 80 percent are in operation each day. 90 percent of the buses in operation are on duty 16 hours per day.and the remaining buses operate 8 hours per day.

The average fuel consumption for the different types of CTA buses is given in Exhibit 6.7. Using the number of Heavy Duty, Nasr 871 and Nasr 811 that are in operation, the weighted average of diesel fuel consumed by the three types of heavy duty buses = 56.56 liters per 100 km.

6.2.3 Data Tables

The CTA Bus case is well documented as described above. The other cases selected for analysis are not as well documented. The study team met with individuals from the Cairo Beverage and Industrial Company and obtained significant data through discussions with them. For the passenger car and light duty truck cases, the study team developed input data based on discussions with numerous individuals in all sectors. These were the least well documented. In some instances, estimates were made based on the teams' experience and background. Input tables describing the above described inputs and for other options investigated are provided below.

Exhibit 6.10 **Input Data for the CTA Bus Fleet for a Typical Garage**

	CTA BUS RETRO DUAL-OPEN LOOP	CTA BUS RETRO DEDICATED	CTA BUS NEW ENG DEDICATED	CTA BUS NEW BUS DEDICATED	CTA BUS RETRO DUAL-CLOSED LOOP
Number of Vehicles	220	220	220	220	220
Average Number of Vehicles Operating	176	176	176	176	176
Diesel km/l	1.77	1.77	1.77	1.77	1.77
CNG km/l Equivalent	1.41	1.5	1.58	1.58	1.57
Daily km/Vehicle	270	270	270	270	270
Hrs Parked (slow)	7 (15)	7 (15)	7 (15)	7 (15)	7 (15)
Change in Lead, g/km	—	—	—	—	—
Change in CO, g/km	11.3	-21.7	-21.7	-21.7	-20.4
Change in NMHC, g/km	+2.2	-2.2	-2.2	-2.2	-2.2
Change in NOx, g/km	-7.4	-11.0	-11.0	-11.0	-11.2
Change in SOx, g/km	-0.9	-1.7	-1.7	-1.7	-1.5
Change in PM, g.km	-1.9	-2.4	-2.4	-2.4	-2.4
KIT $	2500	3600	2500	2500	5000
Tanks Size (SCF)	784	784	784	784	784
Number of Tanks	8	10	10	10	8
Tanks Cost, $	3200	4000	4000	4000	3200
Labor Hours	64	70	30	30	64
Percent km on CNG	70	100	100	100	85
Days per Year Operation	365	365	365	365	365
Inspection Hours	11	14	14	14	11

Exhibit 6.11 **Input Data for Cairo Beverage and Industrial Company Trucks**

	TRUCK RETRO DUAL-OPEN LOOP	TRUCK RETRO DEDICATED	TRUCK NEW ENG DEDICATED	NEW TRUCK DEDICATED
Number of Vehicles	200	200	200	200
Average Number Vehicles Operating	160	160	160	160
Diesel km/l	3.23	3.23	3.23	3.23
CNG km/l Equivalent	2.82	2.87	2.91	2.91
Daily km/Vehicle	100	100	100	100
Hours Parked	7	7	7	7
Change in Lead, g/km	—	—	—	—
Change in CO, g/km	+2.9	-13.2	-13.2	-13.2
Change in NMHC, g/km	+2.7	-2.5	-2.5	-2.5
Change in NOx, g/km	-1.5	-7.0	-7.0	-7.0
Change in SOx, g/km	-0.9	-1.7	-1.7	-1.7
Change in PM, g/km	-0.2	-0.7	-0.7	-0.7
Kit $	2500	3600	2500	2500
Tank Size (SCF)	784	784	784	784
Number of Tanks	2	2	2	2
Tanks Cost, $	800	800	800	800
Labor Hours	46	46	6	6
Percent km on CNG	70	100	100	100
Days per Year Operation	312	312	312	312
Inspection Hours	6	6	6	6

Exhibit 6.12 **Input Data for Petrobel Passenger Car and Light Truck Fleets**

	PASSENGER CAR RETRO BI-FUEL	PASSENGER CAR NEW DEDICATED	LIGHT TRUCK (PICKUP) NEW DEDICATED	LIGHT TRUCK (PICKUP) RETRO BI-FUEL
Number of Vehicles	150 of 300	150 of 300	150 of 300	150 of 300
Average Number Vehicles Operating	120	120	120	120
Gasoline km/l	10.6	10.6	7.8	7.8
CNG km/l Equivalent	11.55	11.24	8.19	8.39
Daily km/Vehicle	55	55	100	100
Hours Parked	16	16	12	12
Change in Lead, g/km	-.056	-.07	-.08	-.084
Change in CO, g/km	+2.9	-13.2	-13.2	-13.2
Change in NMHC, g/km	-6.5	-25.5	-29.8	-7.9
Change in NOx, g/km	-0.2	-0.9	-1.04	-0.2
Change in SOx, g/km	—	—	—	—
Change in PM, g/km	—	—	—	—
Kit $	200	350	350	200
Tank Size (SCF)	459	459	459	459
Number of Tanks	1	1	2	2
Tanks Cost, $	350	350	700	700
Labor Hours	13	13	16	16
Percent km on CNG	80	100	100	80
Days Per Year Operation	272	272	272	272
Inspection Hours	3	3	6	6

Section 7.0 Economic and Financial Analysis

7.1 Description of Economic Model

7.1.1 Overview

An economic spreadsheet model has been constructed for a broad-based examination of alternative transportation uses of natural gas in Egypt. The model is capable of providing better prediction for large fleets than for small fleets. However, since larger fleets are more likely to be economically justified, this "bias" is considered acceptable for this level of feasibility review. The model is currently on a Macintosh version of Excel spreadsheet software. Model input and output sheets which have been used in the results tables found later in this section can be found in the Appendices for the cases/options analyzed. One copy of the model is provided here as Exhibits 7.1 (Input Sheets) and 7.2 (Output Sheets) Basic input segments of the model include:

- Vehicle input data, such as number of vehicles, average km per day, fuel economy, conversion costs, etc. (across top of Exhibit 7.1)
- Fuel-related inputs, such as gas price pressure, distance to distribution network, electricity price, diesel price, etc. (left hand side of Exhibit 7.1, under vehicle data input)
- Station design factors (approximately in the center of Exhibit 7.1)
- Miscellaneous economic inputs, such as discount rate, labor rate, tax rate, land cost, exchange rate, etc. (two boxes on the lower middle and lower right of Exhibit 7.1)
- Import cost shares, uses estimates of percent of components imported (right hand side of Exhibit 7.1, under vehicle data input)

Basic output data is included in segments that list:

- Station capital and operating costs (upper left of Exhibit 7.2)
- Vehicle capital and operating costs (top middle of Exhibit 7.2)
- Vehicle fuel savings and emissions benefits (top right of Exhibit 7.2)
- Costs and benefits and various economic performance parameters from the fleet owner's perspective (center of Exhibit 7.2)
- Design values estimated for key station components - the compressor and the gas storage bottles (upper middle of left side of Exhibit 7.2)

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- Net export and import effects and emissions reductions effects from the Egyptian Government perspective. (middle right of Exhibit 7.2). Note that the estimates in this section are not estimates of revenue to the Egyptian Government. Rather, they are the net effects to the Egyptian economy as a whole, most of which accrue to citizens.

Undiscounted cash flows for the project in Egyptian pounds, through year 12 (usually annual costs and benefits have stabilized by this date) (bottom of Exhibit 7.2). The simple payback can be determined by examining the values in the bottom row on Exhibit 7.2 (Cash Outlay Sum) and determining the year when cumulative cash outlay becomes negative (in other words becomes a net inflow).

The model is based on 15 year Net Present Value, but has an option to analyze a ten year time horizon (see lower right of Exhibit 7.1). The model includes detailed calculations outside the area of the spreadsheet images used for inputs and outputs. At the end of this section results of use of the model to examine the economics of a range of alternatives will be presented. First the important technical and economic properties of the compressed natural gas fueling station and vehicle conversion system will be described.

The installation of a compressed natural gas station and conversion of vehicles is a capital intensive (high cost) investment which requires a relatively large energy equivalent price difference between oil and natural gas (the gas being cheaper) for a reasonable rate of return. The flow of capital costs versus fuel savings benefits and annual operating costs is illustrated in Exhibit 7.3, while the flow of annual and cumulative net benefits are illustrated in Exhibit 7.4. This is an illustration of an advantageous case. The concept of the simple payback (undiscounted) is illustrated in Exhibit 7.4. The point where the cumulative annual benefits shift from outflow of dollars to inflow (year 6 in Exhibit 7.4) is called the simple payback period, and is often used as a crude indicator for ranking alternatives in preliminary engineering cost studies.

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 1A | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14560	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			**Diesel**					**SOx**				**PM**						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINO	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Boiler	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1131
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed	
(Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

VALUE OF EMISSIONS REDUCTIONS	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

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Fig. VII-1 Input Sheet for the CNG Benefit vs. Cost Model

Exhibit 7.1. Input Sheet for the CNG Benefit vs. Cost Model

Exhibit 7.2 Output Sheet for the CNG Benefit vs. Cost Model

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 1A | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($322,570)
Compressor	($648,718)	Power	($330,005)
Storage Tanks	($65,188)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($213,500)		
Installation	($593,054)		
Subtotal	($1,590,783)		($654,850)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicle			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngin	$9,102,386	$2,163,479
Subtotal		$9,102,386	$2,163,479

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per Hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,590,783)
Station Operation Costs	($654,850)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($4,038,416)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$5,063,971
BENEFIT/COST RATIO	2.25
SAVINGS (COSTS) PER LITER	$0.042
SAVINGS (COSTS) / VEHICLE	$28,773
INTERNAL RATE OF RETURN	45%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,215,606
EMISSIONS CHANGE EFFECTS		$2,163,479
TOTAL BENEFITS LESS COSTS		$7,227,449

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngin	11.5	12.7

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ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3459	2510	2610	2668	2746	393	393	393	393	393	393	393
Fuel Savings	933	1866	2825	3758	4690	4690	4690	4690	4690	4690	4690	4690
Net Cash Outlay	2526	644	-215	-1090	-1945	-4298	-4298	-4298	-4298	-4298	-4298	-4298
Cash Outlay Sum	2526	3171	2956	1866	-79	-4377	-8674	-12972	-17270	-21568	-25866	-30164

Exhibit 7.3 Illustration of Flow of Costs and Fuel Savings Benefits for an Advantageous Case (1A)

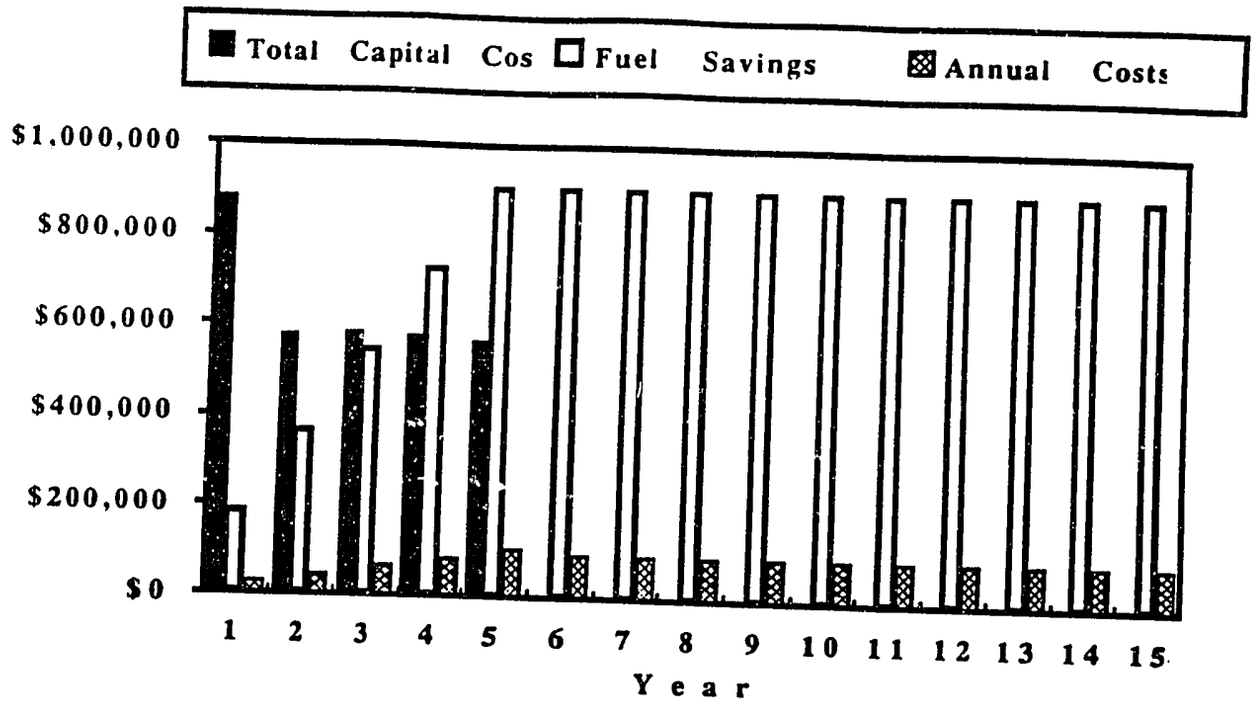
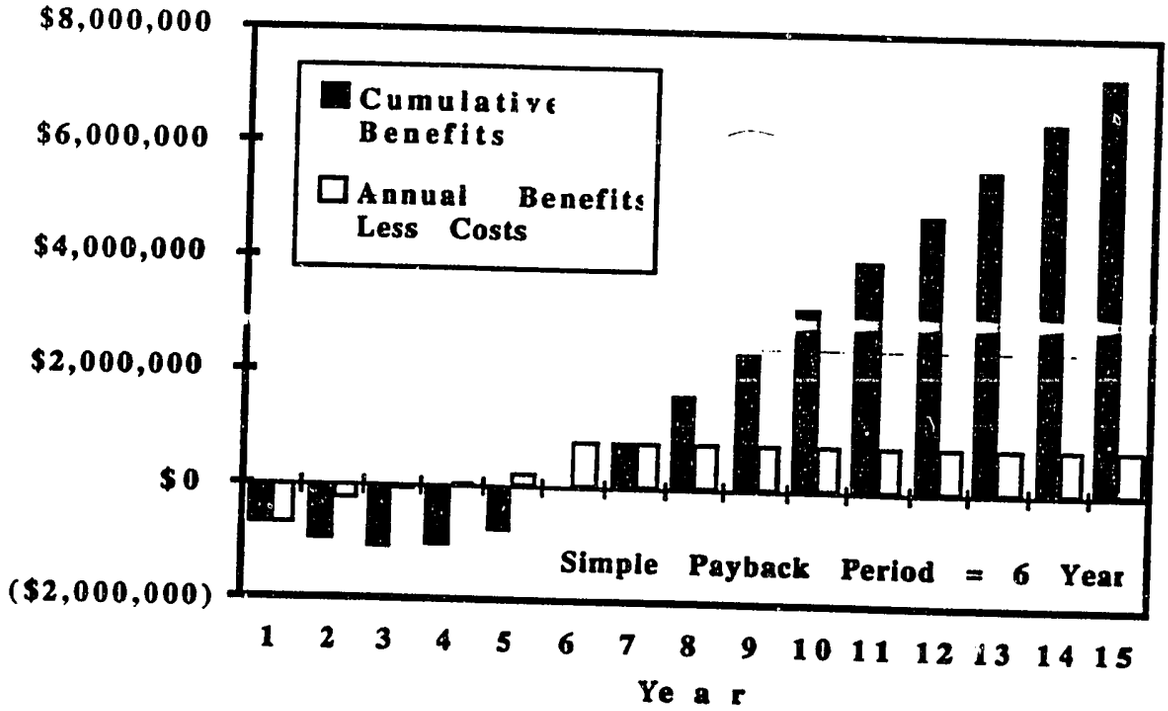


Exhibit 7.4 Illustration of Flow of Net Benefits for an Advantageous Case (1A)



In this study we use the more sophisticated measures of discounted benefit to cost ratio (we use 10 percent real interest) and internal rate of return. All calculations are done in constant dollars for year one of the project (≈ 1994). However, the simple payback point can be determined from the model outputs at the bottom of the output sheet.

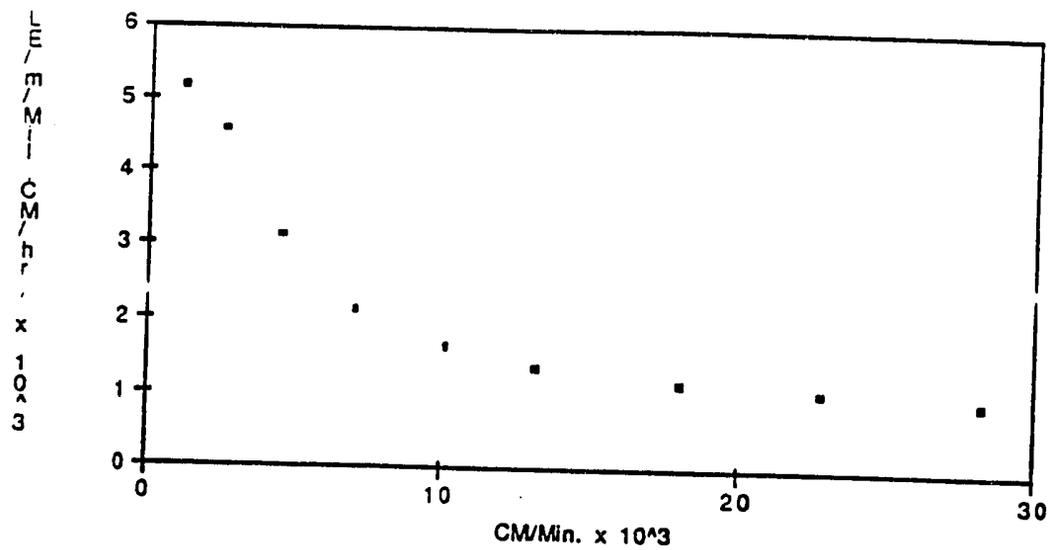
7.2 Input Data

7.2.1 Gas Connection Costs

Physical/engineering properties offer significant economies of scale in delivery of natural gas, both in the gas supply network and in the CNG compressor station itself.

In the natural gas delivery system, the cost of pipeline per unit of volume of gas carried drops sharply as the size of the pipe increases. The cost of connecting a CNG station to a gas pipeline can be considerable, especially if the station has a small volume of flow and is far from the source natural gas transmission or distribution line. A calculation done in dollars (@ 3.37 LE/$) indicated that the dollars per cubic meter deliverable per hour per meter of pipe would be $1.64 if a 14 inch pipe served a typical CTA bus garage, but would drop to $1.12 if a 20 inch pipe line were to serve two such garages. There are three pairs of garages in the CTA system which are candidates for a single pipeline serving both, affording considerable potential for economies of scale in connection costs for those stations. In the case just discussed above, the incremental cost of the 20 inch line compared to the 14 inch line is $0.66, about 40 percent of the cost per unit for delivery by the 14 inch line. Obviously, these properties suggest that, in the event that CTA bus garages support construction of gas pipelines to the garage(s), the pipeline(s) should be oversized and additional customers solicited so that the average costs can be reduced. (Note that several GCBC garages are located near CTA garages and could be tied in as well.)

Exhibit 7.5. Estimated Relationship Between Cost of Movement of Natural Gas, in Egyptian Pounds per Meter of Pipe Length, per Million Cubic Meters per Hour Delivered, at 20 m/sec at 30 Bar (data courtesy of Egypt Gas)



The practical and economic impacts of the cost of delivering gas as a function of the volume demanded by the customer are illustrated nicely by average U.S. data. There are five major categories of customer for which cost data are averaged in the U.S.(U.S. Energy Information Administration) These are, in order of cost, "transportation, electric utilities, industrial, commercial, and residential". The transportation category refers to compressor stations adjacent to major U.S. pipeline which pressure to a transmission line and at as high a pressure as exists in the system (see discussion below). Such gas is nearly as cheap as the wellhead price of gas. In the U.S. in 1990, this price was $1.95 per thousand cubic feet. The next most expensive gas was that sold to electric utilities, for which the price was $2.38 per thousand cubic feet. For industrial customers the price was $2.93, for commercial customers it was $4.82, and for residential customers it was $5.82. Note that the residential and commercial prices were more than twice the price of transportation and electric utility gas. This provides some degree of illustration of the very high costs of transporting gas through a distribution system to small and dispersed customers. We noted that the level of demand for a typical Cairo Transit Authority Station, if converted to natural gas, would be far above the demand of the one industrial customer that we visited, the Cairo Beverage and Industrial Company. The high costs of gas delivery illustrated here are related not only to pipeline costs, but also to costs of metering the gas for small customers. The effects of metering costs were recognized in this study and steps to hold the cost down were assumed, as discussed below.

7.2.2 Onboard Vehicle Storage Cylinders

Economies of scale are evidenced in other components of the overall CNG system, including a beneficial effect in the vehicles components. The volume of a cylinder of a given length rises in proportion to the square of the radius of the cross-section of the cylinder, while the material used in the cylinder rises in proportion to the radius. The complexity of construction stays about the same. Accordingly, the costs of storage per unit volume decline with the volume of the cylinder storage capacity. In the case of the costs of CNG fuel tanks from one U.S. supplier, we found that the retail price of one of the smallest tanks led to a cost of $1.58 per cubic feet (188 LE per cubic meter), while the largest tank cost $ 0.84 per cubic feet (100 LE per cubic meter), a little more than half as much (Pressed Steel Tank, 1994). Note that we assume lower costs in our analysis because we assume large quantity purchases of the fuel tanks. The costs used in the discussion above were from a sales representative quoting retail prices if only one tank were purchased.

Larger vehicle storage tank size also impacts positively on vehicle fuel tank weight carried per unit of volume of gas stored. In the case of the smallest and largest capacity tanks sold by the U.S. manufacturer discussed above, the smallest tank weighs 3.7 kg per cubic meter of gas carried when full, while the largest tank weighs 3.4 kg per cubic meter. This is obviously a smaller effect than the cost effect, but it does contribute to reduction in the proportional losses in fuel economy due to tank weight.

The vehicle itself may be thought of as a container also. As the outside dimensions of a vehicle increase, space inside the vehicle tends to increase more rapidly than the weight of the vehicle. As a result, available room for placement of storage cylinders tends to be more readily found

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in larger vehicles. In the U.S., those CNG vehicles being developed by Ford, General Motors, and Chrysler tend to be vehicles of larger sizes, such as standard pick-up trucks, vans, and large sedans.

7.2.3 Conversion Kits

The U.S. supplier IMPCO produces kits for engines above and below 4.0 liters. The Italian supplier to PETROBEL, however, was indicated by PETROBEL engineers to supply kits in sizes for engines above and below 2 liters. Generally, a kit for a light duty car or truck with a 1.0 liter engine, from either the U.S. or Italy, would cost approximately the same as a kit for a vehicle with a 2.0 liter engine. The relative cost for conversion would therefore be greater for the smaller vehicle. At the same time, the smaller vehicle has better fuel economy, using fewer liters per kilometer, effectively saving less money per kilometer using CNG than the large car. So, the ability to pay off the costs of the kit would be greatly diminished in the smaller vehicle. Generalized, these properties of CNG storage and engine conversion systems tend to work against economical implementation in smaller vehicles.

As was the case for kits, we found that the U.S. tends to specialize in equipment for larger vehicles. The range of fuel tank sizes offered by the U.S. supplier that we investigated (Pressed Steel Tank, 1994) started and ended with larger tanks than did the range offered by the Italian supplier (Barker,1990). Consequently, the comparative advantage that might exist for Italian suppliers relative to U.S. suppliers for small passenger cars should disappear in the range of vehicle sizes that includes buses.

7.2.4 Compressor Systems

The pipeline distribution system itself impacts the capital and operating costs of the station. Gas is transmitted from wells to Cairo in large diameter pipelines operating at high pressure. Once at the edge of Cairo, the gas is transmitted into Cairo in smaller diameter feeder lines. As these lines become smaller and smaller in diameter, the pressure in the lines is dropped. The major transmission line serving Cairo operates at 30 bar, while a second large line operates at 7 bar. Lines serving residential areas generally operate at a pressure of 3 bar. The recently opened PETROBEL CNG service station (currently serving only PETROBEL CNG vehicles) taps into a gas line which operates at 3 bar. Based on the characteristics of the types of compressors used for CNG, it is a considerable advantage to tap into a major pipeline at higher pressure. This is logical, since the gas stored in the vehicles has to be compressed to about 200 bar. Thus, the higher the starting pressure from the gas pipeline, the lower the energy requirements to compress the gas further to the level required in the vehicle storage tanks. The benefits of starting with a higher inlet pressure to the compressor include lower electricity (or other power/fuel) cost for compression, and lower capital cost for the compressor itself, since it requires fewer stages. Our source for the relative magnitude of these effects was Filidaro (1990), who had prepared a discussion of the trade-offs involved in developing a station for a group of intercity buses.

From the data points developed by Filidaro for **electric power requirements** per unit of gas compressed, a continuous curve was developed by regression analysis for use in the model. The

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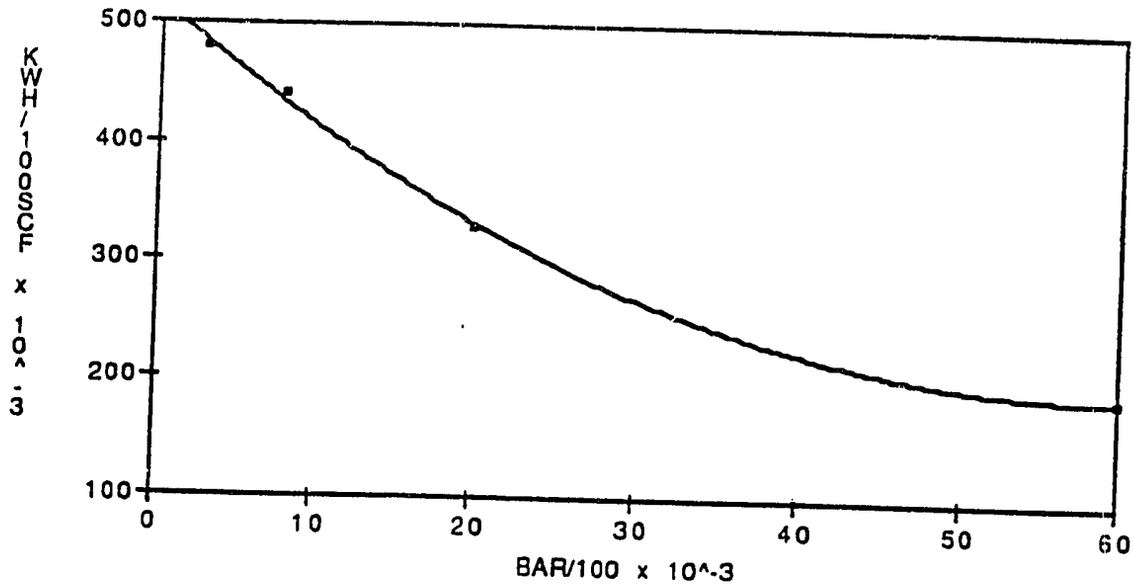
intercept term for this curve was about 0.5 kWh per 100 SCF (17.7 kWh per 100 m^3). A 1983 estimate of power requirements for a representative U.S. station for a few light duty vehicles, operating at 0.5 bar, was 1 kWh per 100 SCF. We presume that contemporary and large compressors (such as those used in a bus station) are more efficient than those assumed in the 1983 U.S. analysis, and therefore we used the more general formulation base on Filidaro. It is worth noting that the compressor can be powered by an on-site generator fueled by the gas in the pipeline. We have not analyzed this option, assuming instead that the electric power for compression will be provided by EEA.

Exhibit 7.6 Estimated Electric Power Requirements per Unit of Gas Compressed, for Varying Inlet (Suction) Pressures Into the Compressor (source: Filidari, 1990)



For compressor costs, Filidaro also presented estimates of the effect of inlet (suction) pressure on the capital cost of the compressor. In this case the relationship was not a smooth curve, but seemed to be consistent with the existence of a "kink" in the cost curve. Filidaro presented estimates at 3, 8, 30, and 60 bar. Costs per unit of capacity varied most when going from 3 to 8 bar, and then remained roughly constant thereafter. It is presumed that the increase from 3 to 8 bar allows the elimination of a fixed number of stages in the compressor, and further

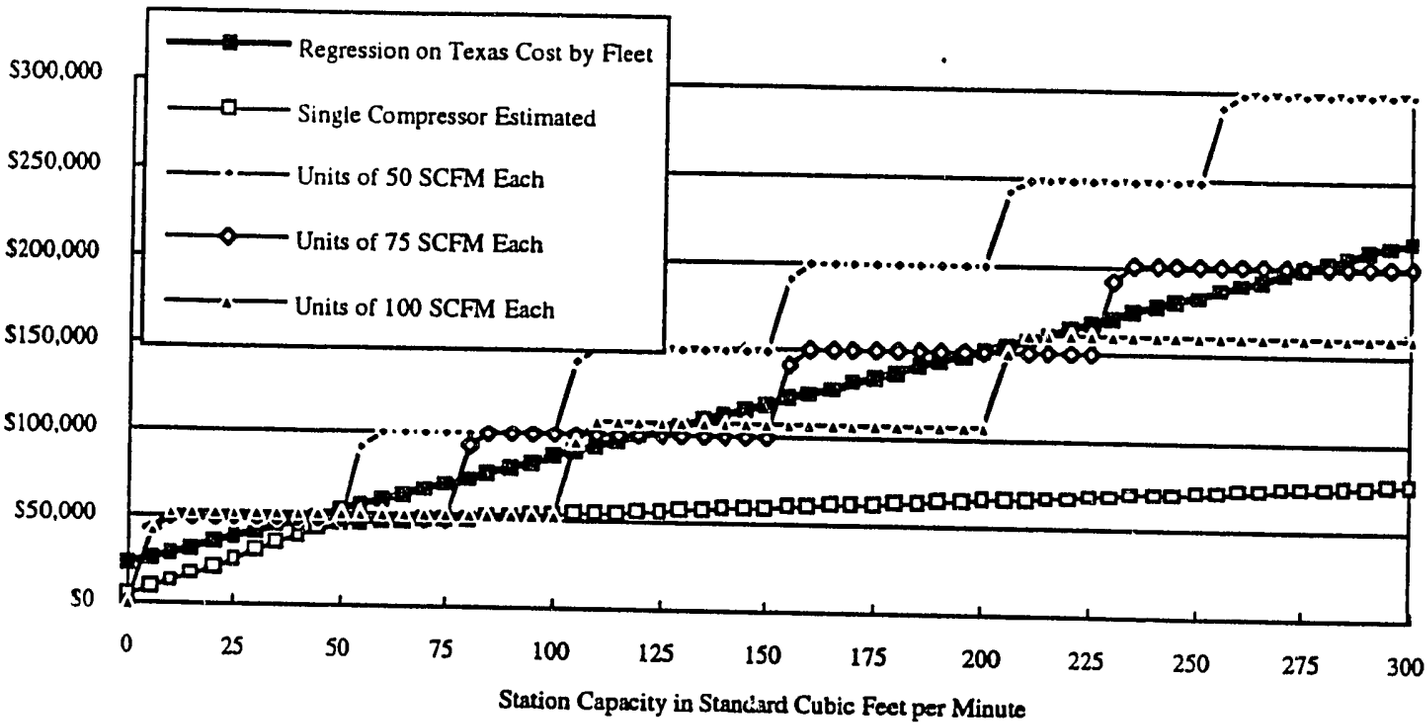
pressure increases do not. The model allows the user to specify the fraction of cost of compressors operating at 3 bar in order to estimate the beneficial cost effect of increases in compressor inlet pressure. The value used in this study was 0.56, and it was presumed to take effect at 7 bar. This is a critical assumption that should be verified when making specific estimates based on information from particular compressor suppliers.

The model includes a general **compressor cost-versus-size** function, which is a straight line with a positive intercept. The base compressor cost values suggested for inclusion in the model, and used in this analysis, apply to compressors of 50, 75, and 100 SCFM marketed by Norwalk of the U.S.(Barker, 1990.) A rough quote was also obtained on a small household compressor (Fuelmaker, 1994) and storage system. The compressor cost was $3500 (11800 LE @ 3.37 LE/$) with a capability to deliver the equivalent of one gallon of gasoline per hour (125,100 BTU's/hr at values used in this study, and 2 SCFM at U.S. gas BTU content [1035 BTU/CF]). This compressor was designed to work at 0.14 bar, while the Egyptian gas system pressures that the team was familiar with were 3 bar at a minimum. The cost of a 50 SCFM compressor was $39,700, in 1990, escalated at 10 percent to 1994, and 9.7 percent more to Cairo for shipping and insurance. The next two compressors were the Norwalk 75 SCFM at $41,500 in 1990, and the Norwalk 100 SCFM at $44,500 in 1990. The costs per SCFM of service for these compressors drop sharply at each step up in size. $1750 per SCFM (3470 LE/cubic meter/hour) for the 2 SCFM (3.6 cubic meter/hour) unit, $870 per SCFM for the 50 SCFM unit, and $490 PER SCFM (970 LE per cubic meter per hour) for the 100 SCFM unit. 550 SCFM compressors have been put to use in a Canadian bus garage CNG station. Note that the typical CTA bus garage examined later is estimated to require capacity equivalent to four 550 SCFM compressors.

The costs of compressors were examined against those obtained from a study by Taylor, Euritt, Mahmassani (1992,1993) and determined to be similar to the costs implied by that study. A minimum cost function was constructed, but it was based on the assumption of a single compressor. It was recognized that multiple compressors would be desirable, since the consequences of failure of a single large compressor serving the whole station would be severe. One would probably prefer to have at least three compressors per station. For the CTA bus garages, the model inputs developed so far imply numerous 100 SCFM compressors, so the safety in numbers is great and the need for reserves small. If larger compressors are of interest in practice for CTA garages, the station designers will want to carefully consider the consequences of failure of compressors and its relationship to the most desirable size and number to purchase. The model provides suggested compressor cost functions to simulate multiples of 50, 75, and 100 SCFM. Investigation indicates that 100s are cheapest, even at small station sizes.

We suspect that the optimized size of the individual compressors for the CTA fleet applications will be larger than 100 SCFM after detailed engineering design is completed, however, the total system cost estimates developed by the model are satisfactory for feasibility study purposes.

Exhibit 7.7 Potential Costs of Compressors Functions Examined Over a Limited Size Range of Station



7.2.5 Refueling Station Design

The model is set up to simulate two fundamentally different approaches to station design. The model is designed to handle fleets, and was configured with the CTA bus garage situation in mind because of the preliminary indications that these would be the most economical locations. Most of the operating buses return to the garage for a relatively short period of time, from about midnight to six AM. Most buses run two eight hour shifts, with about 10 percent running only one eight hour shift. Those buses which run on an eight hour shift can be parked for nearly sixteen hours and are therefore candidates for "slow fill" operation, which allows use of a cheap refueling stand (with no metering) and allows station storage for those buses to be avoided. The compressor directly fills the buses.

One station concept is to have compressors fill station storage bottles over a period of several hours and then have the vehicles quick-filled at a dispenser like those found at a gasoline station and in a comparable amount of time. This design allows reduced compressor capacity, but requires expenditure on storage bottles. When compressor costs are high relative to storage bottle costs this option is more advantageous. Taylor, Euritt, Mahmassani (1992,1993) asserted that maximization of storage was always desirable, but the range of gas throughput of the typical station that they examined was far less than that which would occur at CTA bus garage stations. As was illustrated above, at low volumes of compressor capacity, costs per unit of gas delivered appear to rise sharply. If this option were adopted, the compressor would be on during most of the day while buses were in operation, and would run infrequently during the period from midnight to early morning when the buses were filled.

The second station concept is to have a large compressor capable of directly meeting the demand of the buses (or other vehicles) when they are filled. With this concept the station compressors are off during the day, but on most of the night. The compressor need some storage to act as a "buffer" between the compressor and the bus and to smooth out variation in pressure from the operation of the compressor. In this model a storage buffer sufficient to provide 1/2 hour of gas demand from the vehicles is provided. With the costs of compressors and storage bottles included in the base runs of the model, it generally proved cheaper to use this station concept. We noted that this is the concept implemented in the bus stations in Canada. The model does capture the changing trade-off between storage costs and compressor costs and does find cases with very small stations to be cheaper when storage, the first option, is used. For the stations of interest in this study, however, the large compressor, small storage concept appears to be most economically desirable. This approach also leaves open the option of using the station to fuel other CNG vehicles during the day.

One drawback of the fast fill option is the loss of storage capacity that occurs as the gas is heated by the fast fill process. This loss depends on the fill rate. Maximum storage is obtained with slowest fill rates. The model does not capture this effect, and consequently favors the second station concept a bit more than it should.

The costs of metering natural gas are a deterrent to its use. Electronic dispensers capable of recording gas flow appear to be very costly - on the order of $25,000 (84,250 LE) per

dispenser, while mechanical dispensers without the monitoring capability cost about one fifth as much. In this study we have assumed that only one electronic dispenser is purchased (the first one) and that mechanical dispensers are used in the rest of the cases. Mechanical dispensers may also dispense gas at a higher flow rate, since the restriction on the flow rate of the electronic dispenser appears to be based on the limitations of the measuring device used. It is assumed that rough records of fuel use are kept by monitoring fuel gauges in the vehicles and when trouble is indicated the electronic dispenser is used to accurately test for fuel consumption rates before and after repairs. The slow fill dispensers are about one fourth of the cost of the mechanical dispenser, but they only serve one vehicle per day, while the mechanical dispenser can serve more than four. The use of the slow fill dispenser, however, can have the benefit of spreading the fill period out, allowing a reduction in size of the compressor and elimination of station storage. The model is designed to estimate the effects of using slow fill in a proportion of the fleet less than 50 percent of the total. It makes estimates of the reduced miles per day of those vehicles which sit idle at the station for more hours, and splits the fuel consumption and refill demands of slow and fast fill vehicles accordingly.

7.2.6 Miscellaneous and Installation, Set-Up and Training Costs.

The costs for miscellaneous capital (gas dryers or methanol injectors, valves, tubing, pipes, connectors, tool kits, gas recovery systems, and equipment manuals) are estimated at 18 percent of the cost of compressors, storage bottles, and dispensers. The study team was not able to develop refinement of the likely variation of these costs with costs of the base equipment of the station. The factor was developed from a Norwalk pilot project bid prepared for the OECP (Barker, 1990). Installation, set-up, and training costs were estimated to be 51 percent of the cost of the compressor, storage bottles, and dispensers. In principal, this cost should decline as a ratio to capacity as station size increases, since the number of pieces to be managed does not increase in proportion to station size. In particular, larger compressors may need about the same amount of set up and training effort per compressor as small compressor. To the extent that compressor costs decline as a share of total costs and relative to capacity, both the "miscellaneous" and the "installation, training and set-up" costs will decline relative to capacity and relative to total costs. The training in U.S portion of the Norwalk bid was not included since the assumption is that the program will be a large one and after the first round of training in the U.S., Egyptians will train one another for remaining stations.

7.2.7 Storage Equipment

Station storage equipment comes in three levels of safety and cost. The American Society of Mechanical Engineers rated system is most expensive and has the highest safety factor. The common system in the U.S. is certified by the U.S. Department of Transportation (DOT3AA), and represents about 38 percent of the cost of the ASME system. The Italian storage bottles cost least, but not much less than the DOT3AA system. The Italian system does not carry either of the U.S. safety ratings. To simulate the ASME system in the model, one enters a factor of 1.04 in the appropriate location on the input page to adjust the base cost function in the model. To use DOT3AA storage bottle cost approximations a factor of 0.39 is entered and to simulate the Italian system a factor of 0.30 is inserted. In the base runs of the model we use the DOT3AA

system cost estimate.

7.2.8 Vehicle Inputs

Specific vehicle inputs used in the analyses discussed here are presented in Section 6. However, some discussion, as pertaining to economic estimates, will be presented here. There are three major categories of vehicles examined - heavy diesel buses (16 tons), heavy diesel trucks, and light duty gasoline vehicles. In each case, conversions tend to decrease peak power, although the degree of loss varies considerably depending on engine and technology specifics. On a thermodynamic efficiency basis, the gasoline vehicle engines are closer in original configuration to the ideal requirements of natural gas fuel. In fact, natural gas has a higher octane than gasoline, and this tends to allow greater efficiency when the compression ratio and/or system control strategies are adjusted properly. Research on standardized test cycles indicates that the energy equivalent fuel economy of CNG conversions from gasoline vehicles, especially for low methane content gas as found in Egypt, can be greater than for gasoline vehicles. We have simulated this as being the case in our modeling. However, field data contradicts the standardized test results (Moussavi and Al-Turk, 1993). This may be due to the fact that the standardized test cycles do not require hard acceleration. Acceleration of natural gas engines vehicles is hampered by the fact that the natural gas displaces air from the cylinder and makes it more difficult to get the equivalent of rich mixtures used in gasoline vehicles during acceleration. Accordingly, in the field, drivers may depress the accelerator to a greater degree in order to obtain desired performance, and thereby degrade fuel economy.

We have generally assumed a lower level of control and a less sophisticated technology in Egypt than is applicable to the U.S. case. This does not mean that we have not estimated dramatic improvement in emissions behavior. We observe that Egyptian vehicles are now uncontrolled. We therefore used U.S. precontrol emissions rates per unit of fuel and adjusted the emissions rates per vehicle kilometer traveled by estimated relative fuel consumption per liter in Egypt as compared to the U.S. The data that we were able to obtain on CNG vehicles tested in the U.S. implied significant CNG emissions reductions from this precontrol level, even with the relatively low technology CNG dual fuel kits using open-loop controls. Open loop controls do not have downstream sensors to adjust the mix of air, natural gas and exhaust gas recirculation coming into the engine cylinder. Closed loop controls monitor the exhaust gas composition and give feedback to the engine controls. More information is collected and used (electronically). The closed loop systems have led to great success in lowering natural gas vehicle emissions in the U.S. Although U.S. customers are not happy with open loop control systems for CNG, we found that the emissions rates unacceptable to the U.S. EPA should be very attractive in Egypt. Since the use of the open-loop control system without a catalyst is much cheaper than the U.S. closed loop systems with catalysts, we decided that the cheaper systems - still a significant improvement - should be considered for use in Egypt. Since we require less sophistication in the emission control system and since most of the vehicles of interest for conversion use mechanical systems, we have assumed the use of mechanical rather than electrical control systems, and we have assumed that there are no catalytic converters on the CNG vehicles. Since there are no catalytic converters on present Egyptian vehicles, this seems the logical assumption.

One thing that we have not done is estimate the difference in cost of reducing emissions by using non-catalyst equipped CNG vehicles with simple control strategies in lieu of possible future implementation of catalytic converters and sophisticated electronic emissions control systems in future gasoline vehicles. This would drive up both the costs of gasoline and the gasoline vehicle of the future. This comparison is desirable and should be conducted in the future, but is beyond the scope of this report.

For the buses and cars, the new engine options do assume a high level of control such as electronic systems. We did obtain quotes from suppliers of U.S. engines, and have since learned what type of emissions control would be used. For the new U.S. heavy duty CNG engines the technology most adaptable to Egyptian heavy duty vehicles makes use of lean combustion to reduce emissions without a catalytic converter. The new U.S. light duty engines (converted from gasoline engines) do use a high level of emissions control, including a catalytic converter which is especially designed for use with CNG. Both the light and heavy duty engines compromise fuel economy for two reasons. They select a compression ratio of about 10:1. Though this is lower than can be attained with most natural gas, it provides a safety factor against gas with a lot of non-methane liquids, as well as gas whose composition is highly variable. A low compression ratio also helps keep combustion temperatures low and thereby keep nitrogen oxides emissions low. This should also improve durability. However, a detrimental effect of the low compression ratios and of spark ignition is relatively poor energy equivalent fuel consumption at idle in comparison to a diesel engine.

The type of emissions control systems to be used in Egypt and their capabilities are an area of uncertainty. We have constructed best judgment estimates to determine how much technically achievable emissions reduction might be worth. The accuracy of these estimates depends on the quality of maintenance of Egyptian vehicles, specific decisions about technology and regulation/inspection.

The value of emissions reduction was obtained from research by Ken Small at the University of California at Davis (Small and Kazimi, 1994). The source was particularly fortuitous since it comprehensively covers all of the pollutants of interest. The damage values are based primarily on health damages rather than regulatory costs. The values of Small and Kazimi were compared to those for various cities in the U.S. and to national average values used in U.S. government studies in 1993. The values estimated by Small and Kazimi are higher than most values used in U.S. studies, partly because they take into account emerging knowledge about detrimental effects of particulate matter and sulfates. The values were adjusted downward for the Egyptian case based on the relative earning power of Egyptians vs. Americans. The GDP per capita of Egyptians was divided by the GDP per capita for the U.S., obtaining a factor of approximately 0.06. Thus, the values started with are historically high, but they are heavily discounted by the assumption that the value of life is commensurate with earning power. The values for emissions reduction which emerge from this calculation are nevertheless noteworthy, suggesting that motor vehicle emissions reductions in Egypt are highly desirable.

The information that we have obtained indicates that the incremental cost of a new CNG engine in production in the U.S., as compared to a new diesel engine of the same make, is lower than

the cost of converting an undeveloped engine to CNG making use of available kits. The feasibility of converting the air- cooled engines used in Cairo Transit Buses has yet to be demonstrated, even if the costs we assume are correct. In the interim, CNG engines appear to be available from the U.S. at costs which are less than the cost of new diesel engines that are routinely purchased for CTA buses. Our new engine options for buses are distinct from the other CNG engine options in the sense that the engines are available now, while others - such as an oil ignited natural gas engine, or dual fuel, closed loop controlled engine (labeled OING in the spreadsheet and termed a Pilot Injection Natural Gas engine [PING] by Detroit Diesel Corporation) or Dual Fuel engine - based on existing air-cooled bus engines have to be developed.

Our examination of engine options pointed toward better economics for new engines than continued use of old technology air cooled engines. Nevertheless, these engines remain to be adequately demonstrated in CTA buses configured for the old engine design.

7.2.9 Other Economic Inputs

The model uses other critical economic assumptions. The life of the analysis typically presented here is a 15 year period, though the model has an option to examine a ten year period. Vehicles are kept in service for that amount of time. Detailed replacement schedules for engines have not been worked out. For gasoline vehicles the model's implicit assumption of a 15 year (or more) life is reasonable. For buses and heavy trucks this is a shortcoming. Discussions of the frequent rebuilds of CTA bus engines suggests that improvement of the reliability of the CTA engines, if it came as a part of a package of switching to new engines, could have a considerable advantage to the Cairo Transit Authority. We do know that the scheduled rebuilds of transit bus engines in Ontario Canada was estimated to occur at 5 and 10 years, presumably with input from the transit operators there (Topaloglu et al, 1991), while engine rebuilds at the Cairo Transit Authority workshop were reported to occur annually after the first rebuild at approximately five years. Obviously, if a program to introduce CNG engines also aided the CTA in increasing the time between overhauls, the benefits of the program would be magnified.

The model works on the basis of assumed real costs, with no differential escalators. The interest rate entered into the model is the real interest rate. Rates on loans, to be considered comparable, would add the rate of inflation to the real interest rate.

The rate of cost of labor included is an option. This analysis uses $5/hour. This rate is to be considered a fully loaded rate for skilled workers. It is presumed to include managerial and equipment overhead.

The days of operation of the fleet can have an effect on the rate at which a fuel economy cost reductions per mile of operation can be retrieved to pay off up-front capital costs. The user must recognize that the annual operating mileage of all vehicles is not entered into the model. To predict how much fuel is used per year, we consider the number of vehicles operating per day, the number of days operating, the fuel economy per kilometer of operation of the vehicle, and the daily kilometers traveled by the operating vehicle. The model requires inputs on the

number of CNG vehicles that must be converted over and above those actually used each day, so that there will be a reserve of operable vehicles for peak days and a reserve of inoperable vehicles under repair. The entry of appropriate values into the model can be deduced by obtaining the proper information from the fleet operator.

In this analysis, we have assumed that the land costs for the station are zero, since we assume that the station can be fitted into the existing garage for the fleet. When this is not the case, land costs can be entered into the model.

A typical rate of taxation of imported products can be entered into the model, and an estimate of the proportion of key components of stations and vehicles which are imported can be entered. The values we have assumed can be found in the appendix. Generally, for our base case, we assume 100 percent imports for compressors, storage bottles, dispensers, vehicle fuel tanks, and vehicle conversion kits. We do not assume imported new engines in the new engine cases, but assume only importation of the CNG equipment to convert an otherwise imported new diesel engine to a CNG engine.

The vehicle inputs permit varying the number of years over which to schedule the build-out of vehicles, compressors, storage systems and so forth. In this analysis it has been assumed that the projects are built over a five year interval.

Fuel Prices: The costs of fuel entered into the model involve four fuels; natural gas to the station boundary; diesel fuel (gasoil) sold internationally at a major port; gasoline sold internationally at a major port; and electricity at the station boundary. The costs of delivering diesel (gasoil) and gasoline from a port to the final consumer are also to be included to properly represent the costs as seen by the garage operator. The costs used for the base case in this analysis are $0.13/liter (0.44 LE/liter) for internationally traded gasoline, and $0.05/per liter (0.17 LE/liter) for retailing/delivery of the gasoline to the customer. It is presumed that gasoline is of lower quality relative to world market demands than is the gasoil that would be displaced by CNG. Gasoil (diesel) is estimated to be worth $0.15/liter (0.51 LE/liter) on the international market. This may vary with sulfur content and is a source of some uncertainty. Retailing/delivery costs are the same per liter as those for gasoline. On May 26, 1994, the New York Harbor futures prices for unleaded gasoline varied from $0.126/liter to $0.14 /liter, while heating oil (which can contain more sulfur than diesel transportation fuel) varied over essentially the same range. Gasoil varied from $0.14/liter to $0.15/liter on the International Petroleum Exchange. Natural gas varied from $1.83 to $2.39 per 10000 MBTU on the New York Exchange, a location to which Algerian (or Egyptian) gas cannot be delivered for less than twice those amounts.

Hertzmark estimated the long run marginal cost of natural gas in Egypt to be $1.57 per million BTUs (0.21 LE /cubic meter of Egyptian gas at 1135 Btu per cubic foot) (Hertzmark, p. 10). We use a price of $1.60 per 1000 cubic feet in our analysis, about $1.41 per million Btu with 1135 Btu/cubic foot Egyptian gas. This is somewhat less than the long run marginal cost estimate by Hertzmark. Current prices are 0.125 LE per cubic meter of gas in Egypt, well below the 0.19 LE per cubic meter price we have used in the base case. In his Annex 2,

Hertzmark estimated the marginal cost of gas to vary from $0.89 to $1.01 per million Btu for extensions of existing gas fields, $1.39 to $2.09 for unproved reserves, 1.27 to $1.75 for currently operating fields, and $1.39 to $2.09 for unproved reserves. Hertzmark's estimate for the ceiling price of natural gas was $2.20/million Btu.

In his Annex 4, Hertzmark used the avoided cost approach to estimate appropriate electricity costs. He obtained $0.046/kWh for peak capacity and $0.020/kWh for off-peak capacity.

The model assumes natural gas prices equivalent to prices charged to an electric plant. It then includes an estimate of the cost of connecting the system to the bus garage CNG station. The costs per meter of distance from the gas transmission line to the station are estimated for a pipe size appropriate to the station demand. The user enters the estimated distance in meters.

7.3 Results

The results are presented in the following two Exhibits. The first of these, Exhibit 7.8, presents a range of cases from buses to heavy trucks to light trucks and passenger cars. The latter, Exhibit 7.9, takes the best case from the first table and conducts sensitivity analyses to determine how robust the best case results are. With the exception of the third column, which presents the benefit/cost ratio, the costs are presented in units of 1000s of dollars. The costs are estimated for a single station serving the number of vehicles with the characteristics listed in section six. The vehicle characteristics are found in that section. Details on the computer runs are provided in an Appendix.

The costs columns present net present values over 15 years of station life. The station and vehicle costs include the costs of converting vehicles, station costs, and maintenance costs. The fuel saving benefits are a present value accounting of the savings in expenditures on fuel. The benefit/cost ratio divides the latter column by the former. The exports less imports column accounts for the present value of the before tax costs of importing such items as compressors, power plant generating equipment, storage tanks for stations and vehicles, CNG kits, replacement parts, and so on. The exports values are derived from the international price obtainable for the displaced gasoline (Benzene) or diesel fuel (Gasoil). The final column estimates the potential emissions benefits of the conversion to natural gas with the specific technology in question. The benefit/cost ratio is completed from the perspective of the owner(s) of the station and the vehicles which use the station. From society's point of view, however, the total benefits should include the emissions reduction benefits. In order to obtain a "social" benefit cost ratio (not presented), the emission decline value and the fuel savings benefits would be added together and divided by the station and vehicle costs.

General results are as follows:

- Bus garages are more economical to convert than commercial truck fleets or light duty vehicle fleets of similar numbers of vehicles.

- For fleets which use a lot of fuel, the station design which uses a large

compressor bank running simultaneously with the refilling of the vehicles is superior to one in which a smaller compressor bank runs most of the day to fill a storage system which then fills the vehicles.

- For the buses, the best option appears to be new engines using already developed CNG technology, when new engines are scheduled to be purchased. For light duty vehicles no options are desirable if a station is built only to serve the light duty vehicles. For the heavy duty trucks the option could prove desirable or undesirable, depending on the price structure that emerges in the future and depending on the degree to which the government of Egypt finds the export/import benefits and the emissions benefits worthy of inclusion in the benefit/cost consideration. As discussed in the model description, large stations serving vehicles with large daily rates of fuel consumption are the most economical.

An interesting option for CTA bus conversion was identified as a result of reviewing the model outputs. The CTA currently overhauls their engines every year after an engine reaches five years age. The overhauls cost about 20,000 LE. If new dedicated CNG engines were installed at that time, it is likely that at least two and possibly three overhauls could be avoided saving 40,000 to 60,000 LE in overhauls. This value would cover all or most of the cost of the new CNG engine and its installation. Some engineering would be required to mount the US manufactured dedicated engines into the vehicles, but these costs should be relatively small.

The following Exhibit illustrates the capital costs, annual costs, fuel savings, net benefits less costs and cumulative benefits by year for Case 1A, new CNG engines. The simple payback is seen to be about five years. If all spending were to occur in the first year, the payback occurs in the third year. Capital costs for the single station total $3,791,650. This figure can be multiplied by ten to approximate total fleet costs: $38,000,000 or LE 128,000,000.

Exhibit 7.8 Summary of Base Economic Cases With Selected Sensitivity Analyses

Case No.	CASE DESCRIPTORS	STATION and VEHICLE COSTS ($1000s)	FUEL SAVINGS BENEFITS ($1000S)	BENEFIT TO COST RATIO (excludes emissions values)	EXPORTS LESS IMPORTS ($1000S)	EMISSION DECLINE BENEFITS ($1000S) (rough estimate)	INTERNAL RATE OF RETURN ($1000S) (excludes emissions $)
	CAIRO TRANSIT BUS CASES						
	New Engine or New Dedicated Bus						
1A	Large Compressor	4040	9100	2.25	7220	2160	45%
1B	Large Storage	5010	9100	1.82	6670	2160	38%
	Retrofit Rebuilt Engine Ded.						
2A	Large Compressor	4430	8900	2.01	6960	2160	38%
2B	Large Storage	5450	8900	1.63	6380	2160	32%
	Retrofit Oil Ignited Gas Engine						
3A	Large Compressor	4180	7660	1.83	5560	2020	34%
3B	Large Storage	5010	7660	1.53	5090	2020	29%
	Retrofit Old Engines Dual Fuel						
4A	Large Compressor	3470	5940	1.71	4620	940	30%
4B	Large Storage	4230	5940	1.40	4190	940	25%
	CAIRO BEVERAGE TRUCK CASE						
	New Engine or New Truck Ded.						
5A	Large Compressor	1430	1440	1.01	691	631	12%
5B	Large Storage	1610	1440	0.90	590	631	9%
	Retrofit Rebuilt Engine Ded.						
6A	Large Compressor	1700	1420	0.84	500	631	7%
6B	Large Storage	1880	1420	0.76	396	631	6%
	Retrofit Old Engines Dual Fuel						
7A	Large Compressor	1380	951	0.69	268	154	3%
7B	Large Storage	1513	951	0.63	191	154	1%
	AUTO/TRUCK GASOLINE TO CNG						
	New Dedicated						
8A	Large Compressor	962	541	0.56	7	83	0%
8B	Large Storage	1020	541	0.53	-27	83	-2%
	Retrofit Old Engines						
9A	Large Compressor	718	432	0.60	97	34	0%
9B	Large Storage	765	432	0.56	71	34	-1%
	SELECTED SENSITIVITY CASES						
5A1	Off-Peak Electricity @ 2¢/kWh	1400	1440	1.03	698	631	12%
5A2	Connection Distance 500 Meters	1290	1440	1.12	689	630	15%
5A3	50 Cairo Beverage Trucks to Existing Petrobell Station (Incremental Cost)	212	360	1.70	234	158	41%
8A1	Ded. Auto & Truck Using CTA Case A1 Station During Day (Incr. Cost)	1530	1440	0.94	322	221	4%
9A1	Bi-Fuel Auto & Truck Using CTA A1 Station During Day (Incr. Cost)	934	1150	1.23	530	91	8%
9a1*	Bi-Fuel Truck Only Using CTA A1 Station During Day (Incr. Cost)	1160	1640	1.41	864	116	18%

Notes: Costs and benefits are estimated in net present value terms using a 10% real interest rate. If internal rates of return are estimated to be less than 10%, then the benefit to cost ratio should be less than 1.0. The benefit to cost ratio presented here is the private rate - it does not include the social value of emissions reduction. To obtain an estimate of the benefit to cost ratio including the social benefits of emissions reduction, add the emissions decline benefits antd the fuel savings benefits together and divide by tht station and vehicle costs.

BEST AVAILABLE DOCUMENT

Exhibit 7.9 Sensitivity Analyses for Case A1

Case No.	CASE A1 MODIFICATION DESCRIPTION	STATION and VEHICLE COSTS ($1000s)	FUEL SAVINGS BENEFITS ($1000S)	BENEFIT TO COST RATIO (excludes emissions values)	EXPORTS LESS IMPORTS ($1000S)	EMISSION DECLINE BENEFITS ($1000S) (rough estimate)	INTERNAL RATE OF RETURN ($1000S) (excludes emissions $)
1A	New Engine or New Dedicated CNG Buses Served by Large Compressors	4040	9100	2.25	7220	2160	45%
1A1	33% Decline in Diesel Price	4040	5900	1.46	4010	2160	23%
1A2	56% Natural Gas Price Increase	4040	7010	1.74	7220	2160	30%
1A3	Double Vehicle Conversion Costs	5500	9100	1.66	6020	2160	29%
1A4	156% Increase in Storage Cost	4200	9100	2.17	7100	2160	43%
1A5	79% Increase in Compressor Cost	4550	9100	2.00	6790	2160	45%
1A6	25% Decrease in Daily Kilometers	3520	6830	1.94	5080	1620	36%
1A7	Double Import Taxes (40%)	4520	9100	2.01	7220	2160	NE
1A8	No Import Taxes	3560	9100	2.56	7220	2160	NE
1A9	33% Devaluation of Egyptian Pound	5000	13900	2.78	11200	2160	90%
1A10	10 Year Time Horizon	3840	6860	1.79	7260	1640	43%
1A11	Triple Labor Cost	4350	9100	2.09	7220	2160	43%
1A12	Triple Slow Fill Fraction	3970	9100	2.29	7260	2160	47%
1A13	Half Fill Rate Dispenser	4100	9100	2.22	7180	2160	44%
1A14	Double Station (twice as many buses)	7770	18200	2.34	14500	4320	50%
1A15	Half Station Size	2180	4550	2.09	3570	1080	38%
1A16	No Slow Fill	4060	9100	2.24	7200	2160	45%
1A17	30% Better Bus Fuel Economy	3530	7070	2.00	5270	2160	38%
1A18	29% More Time for Fast Fill	3760	9100	2.42	7390	2160	52%

Notes: Costs and benefits are estimated in net present value terms using a 10% real interest rate. If internal rates of return are estimaated to be less than 10%, then the benefit to cost ratio should be less than 1.0 . The benefit to cost ratio presented here is the private rate - it does not include the social value of emissions reduction. To obtain an estimate of the benefit to cost ratio including the social benefits of emissions reduction, add the emissions decline benefits antd the fuel savings benefits together and divide by tht station and vehicle costs. NE indicates that the model , as structured on Oct. 30, did not properly estimate this value.

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Exhibit 7.10 **Single Average Station Costs and Benefits Per Year ($1000s) For Case 1A**

YEAR	1	2	3	4	5	6	7	8	9
Total Capital Cost	1001	696	702	696	696	0	0	0	
Annual Cost	25	49	72	95	119	116	116	116	
Fuel Savings	277	554	838	1115	1392	1392	1392	1392	
Net Benefits Less Costs	(750)	(191)	64	323	577	1275	1275	1275	
Cumulative Benefits - Undiscounted	(750)	(940)	(877)	(553)	23	1299	2574	3849	+1275 \YR

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7.4 Sensitivity Analysis

Selected sensitivity analyses are presented in Exhibits 7.8 and 7.9. Some of the results presented in Exhibit 7.8 indicate that some apparently uneconomical cases could become economically positive if particular strategies are followed and economic realities accounted for. Case 5A for the trucks at the Cairo Beverage Company is of interest because the Benefit/Cost ratio is so close to 1.0. Since these vehicles are like the buses in the sense that they run two shifts per day and park overnight, their electricity demand will occur overnight. If the EEA were to grant an off-peak electricity rate of $0.02/kWh the benefit/cost ratio would increase only from 1.01 to 1.03 (see Case 5A1) The standard assumption has been that the station is 1500 meters from a high pressure gas transmission line. If this distance is only 500 meters, the benefit/cost ratio rises from 1.01 to 1.12, a relatively significant increase (Case 5A2). We also observed that the Cairo Beverage Company is only a short distance from the recently opened PETROBEL CNG station. Estimates of the size of that station are rough. However, it should be able to handle several dozens of CNG vehicles from the Cairo Beverage Company. Since the costs of the capital equipment at the PETROBEL station are sunk costs, in economic terms these should not be included in marginal cost decisions concerning current revenue maximization. If this perspective is used, the Cairo Beverage Company could be provided service so long as it covers PETROBEL's operating, maintenance and replacement costs. Case 5A3 examines the case in which Cairo Beverage only is asked to cover the operating, maintenance and natural gas costs caused by the use of the station. In this case the benefit/cost ratio rises to 1.70. If the social benefit/cost ratio is computed it would be 2.44, and would signal that the government of Egypt would increase social benefits by encouraging the joint use of the PETROBEL station by PETROBEL and Cairo Beverage and Industrial Company.

It is also true that the cost estimates used here are rough, so they should be regarded as evidence that a detailed feasibility analysis for Cairo Beverage trucks and other vehicles should be undertaken by Cairo Beverage and Industrial Company, possibly with some government support due to the emissions benefits and export-import benefits.

The final sensitivity analyses in Exhibit 7.8 show that even conversions of cars and light trucks can be economically positive in some circumstances. Note that the most desirable station option for the bus garages leads to availability of a lot of idle compressor capacity during the day. Using the same logic as in the case of the PETROBEL station serving Greater Cairo Beverage, if the bus garage CNG station were made available during the day to other customers who covered the cost of operations and maintenance, and who used the single electronic fast-fill dispenser (with metering), then the benefit/cost ratio for even light duty vehicle automobile and tuck customers would be positive. In case 8A1 we examine the case of 400 dedicated CNG cars and 400 dedicated CNG trucks (which is in excess of the capability of the single metered dispenser) making use of the idle compressor. The incremental benefit/cost ratio increases to 0.94 from an original 0.6. The dedicated vehicles seem too costly to pay off. In case 9A1 we examine the case of 400 bi-fuel cars and 400 bi-fuel light trucks (which may be in excess of the capability of the single dispenser) making use of the idle compressor. The incremental benefit/cost ratio iumps to 1.23 from an original 0.6. If the social benefits are added in the benefit/cost ratio rises to 1.33. In the last case (9A2) we consider the effects if the light duty

gasoline vehicles are like the trucks we have simulated - driven more kilometers per day than cars and using more fuel per kilometer. If all of the vehicles are such trucks the benefit cost ratio rises to 1.41.

In Exhibit 7.9, the results of a large number of alternative sensitivity analyses show that the positive findings for Case 1A are robust. The benefit/cost ratios vary from 1.46 to 2.78, and the internal rates of return vary from 23 to 90 percent. In the worst case the addition of the emissions decline values to the benefit cost calculation increases the ratio from 1.46 to 2.00. According to these calculations, a program to introduce CNG buses eventually in large quantities (several hundreds of buses) seems well worth the effort.

Section 8.0 Environmental Benefits

8.1 Overview: Priority Vehicular Strategies for Improved Air Quality

The sources of the significant air quality degradation of Greater Cairo over the past 25 years are well-documented (World Health Organization/UNEP, 1992; Government of the Arab Republic of Egypt, 1992; USAID/EGYPT, 1992; Faiz *et al*, 1990), and the role of motor vehicles in that degradation is understood, if not precisely quantified (El Kotb & Borman, 1984; El Kotb & Borman, 1987; Nasralla, 1991; Emara, 1987). It remains a major challenge to implement controls that will bring about the most effective, efficient, and lasting reductions in vehicular pollution loading in a manner consistent with other high national priorities. The use of fleet and individual vehicular holdings is expected to intensify over the next several years, and a large portion of Greater Cairo's populace depends significantly on the private car for individual mobility. An implementation process for effective controls can well begin with the adoption of three enforceable strategies:

1. Proceed with the program to convert a large subset of Cairo's transit buses to operate predominantly on compressed natural gas, which will have a measurable near-term effect on the exposure of millions of citizens to potentially harmful small-diameter carbonaceous particles while reducing the atmospheric loading of combustion-produced sulfur dioxide and sulfates that accelerate deterioration of irreplaceable historical monuments. Reductions in ambient concentrations of carbon monoxide and, to a lesser extent, nitrogen oxides in the central area are also possible. In preparing for these conversions, promote similar conversions among centrally-fueled diesel-powered truck fleets in the private sector through a combination of fuel and conversion cost reduction incentives. *Verification of the effectiveness through time of these efforts, which should intensify as momentum for change is sustained, will only be possible if a permanent, quality-assured vehicle emissions test facility has been established.*

2. Establish a certificate-based annual or biennial vehicular inspection program covering all private cars and light trucks traveling through Central Cairo, as called for by the GOE *Environmental Action Plan (EAP)* that employs an inspection procedure emphasizing control of carbon monoxide through proper tuning of the (predominantly carburetted) light duty fleet: most required adjustments will be relatively simple and enhance efficient use of the fuel.

3. Phase down the maximum lead content of gasolines sold for vehicular use to 0.15 g/liter, as also called for in the *EAP*, utilizing replacement (for tetraethyl lead) octane enhancing agents such as tertiary butyl- and amyl-ethers that can be produced from natural gas feedstock and do not dramatically increase the volatility of the retail gasoline product. If the introduction of *un*leaded fuel is not feasible (due to the age of most of the engine fleet) in the near term, promote the conversion of as many post-1980 model, in-use light-duty vehicles as possible to bi-fuel spark-ignited gasoline/CNG units that would not use catalysts. Begin with centrally-fueled government-owned auto and light truck fleets. This conversion would not significantly reduce carbon monoxide or oxide of nitrogen loading,

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but would run only part of the time on leaded fuel and thus achieve a greater reduction in lead exposure than the 0.15 g/liter fuel lead content alone. As these units are retired, they should be replaced with either, a) dedicated CNG-fueled vehicles, or b) three-way catalyst-equipped vehicles running on no-lead gasoline.

Because the present study comprehensively treats only transit bus conversion in its analysis of feasibility, costs, and benefits, that is the only component of the first strategy above that is analyzed in this report, although a broader conversion strategy such as # 3 is discussed in specific contexts. Our findings endorse and amplify upon conclusions of the references cited above that assign high priority to reducing ambient lead, fine particulate, and carbon monoxide for mitigation of the most serious present insults to public health due to vehicular emissions in Greater Cairo. Conversion of transit buses will contribute to source mitigation of the latter two of these insults.

8.2 Air Quality/Emissions Data Available and Sources Consulted

8.2.2 Air Quality Data Availability and Quality

There is no continuous, quality-assured ambient air monitoring network in place in Greater Cairo for the full range of mobile-source related pollutants. Continuously reliable performance has not been certified for the fixed monitors for SO_2, TSP and black smoke that were in place as of 1992 at eight locations in Greater Cairo (WHO/UNEP, 1992), a fact substantiated in discussion with Dr. M.M. Nasralla of the Air Pollution Department of the National Research Centre (Nasralla, 1994). Reliable information about levels of other air pollutants around Greater Cairo is either anecdotal (one-time measurements taken at irregular intervals over a multi-year period predominantly using mobile sampling equipment) (El Kotb & Borman, 1987), or derives from special studies conducted for individual major point sources (e.g., the Shoubra el-Khaima electricity generating station). Many of these measurements were made under the direction of Dr. Nasralla (Ali *et al*, 1986; Nasralla, 1990; Nasralla & Shakour, 1981). Other studies under the direction of Prof. M. el-Kotb of the University of Cairo, including a study of air and noise pollution in the vicinity of Cairo International Airport that began in 1992, have utilized a portable battery of monitoring equipment for all priority pollutants that can be established at any vertical position as well as remote site (el-Kotb, 1994). State-of-the-art equipment and techniques were used in these studies, which means that most data they collected since about 1980 are reliable indications of the actual concentrations that existed at the time. Of course, any "snapshot" taken in the midst of a period (1980-90) in which vehicles in use were more than doubling is probably well out of date within two to three years. In particular, Central Cairo's air quality trends during the present gradual conversion of the Shoubra el-Khaima facility to natural gas firing have not been documented.[1]

[1]Although Dr. Nasralla (*supra*) reported to us informally that the most recent ozone measurements in central Cairo did not indicate that excursions of the U.S. standard 0.12 ppm standard were taking place, and that recent--although unreleased--monitoring information for suspended particulate level indicate that it is rising at about 3 percent per year. He noted that peak ozone concentrations are observed a) shortly before dawn, and b) for five to six hours during the mid-afternoon. Such results are consistent with the conditions described in the introduction to Sec. VIII.C.

8.2.2 Emissions data availability and quality.

There is no mobile-source emissions inventory for Greater Cairo, although at least one heroic effort in the past has sought to quantify the instantaneous vehicular contribution of CO and NOx on an hourly basis for purposes of dispersion modeling. (El Kotb & Borman, 1987). Direct measurement of vehicular emissions has largely been restricted to two multi-vehicle testing programs undertaken a) in 1992 at MISRLab (Engr. M.M. Kamel, 1994), and b) in 1994 under the authority of the Ministry of the Interior (Gen. M.A. Gaber, 1994); and in topical analyses conducted at the University of Cairo (el-Kotb, 1994). In cases a and b, a sample of in-use vehicles was taken off the road and tested for tailpipe CO, unburned hydrocarbons and CO_2. The objective of both investigations was to identify the distribution of exhaust emission rates enabling determination of appropriate pass/fail cut points for a proposed emissions inspection program in conjunction with vehicle re-registration. (It is possible that the reliability of the earlier study's results was hampered by the fact that vehicles that may have exceeded 10 percent CO exhaust by volume were only recorded at 10 percent, the maximum reading on the analyzer scale.) From a reliable source who must remain anonymous, it has been learned that about 25 percent of vehicles tested exceeded 7% volumetric CO and 1000 ppm hydrocarbon, an indication of poor engine performance possibly remediable by something as simple as a tune-up, but that very few of the vehicles exceeding this threshold were taxis (whose owners well understand the connection between improper engine tune and excessive fuel consumption/operating cost).

8.3 Existing Environmental Conditions

8.3.1 The overall picture

Greater Cairo has been compared to Los Angeles with respect to its insolation, lack of rainfall, and light winds with their frequent inability to fumigate the urban air effectively (Emara, 1987). Another appropriate comparison might be drawn to Las Vegas, in that it is a desert regime characterized by: strong vertical advection with limited horizontal advection or wind transport in daylight hours; and, significant lowering of the mixing layer ceiling at night is undergoing rapid, private transportation-intensive urbanization. The occasionally massive pollutant loading undergone daily by the Cairo airshed can be trapped at night by the desert inversion, and becomes starkly visible as day dawns when it renders many surface features at a distance invisible. With the rising of the sun and the temperature, this pall appears to dilute somewhat with the onset of strong vertical advection, but returns again toward sundown. The suspended particulate, that include significant amounts of sulfate and fine particulate, are strongly suspected, as are nitrogen oxides and, possibly, ozone (Nasralla, 1991). Round-the-clock persistence of these airborne substances is especially troubling in a metropolis like Cairo, in which a large segment of the population on any given day may breathe outdoor air on a 24-hour basis and whose waking-hour activities may keep them in close proximity to vehicular sources for a large portion of the day. Although CO and lead concentrations subside as traffic abates (El Kotb & Borman, 1987), lead deposited from the preceding days' vehicular fuel combustion accumulates on the street, to be swept up again by the following days' vehicular movements and possibly inhaled or ingested on food as carbon monoxide reaches high concentrations. It is indeed a disturbing and ultimately dangerous cycle that cries out for abatement of its direct and severe insult to health.

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8.3.2 Emissions testing, measured concentrations, and expected activity relationships

As described above, ambient monitoring data for Greater Cairo are very sparse and almost non-existent for the decade of the 1990s. Thus, relying on the 1980s information available to us, limited summary statements about the relationships between these concentrations and combustion activities in Cairo can be made about the pollutants of interest.

Air pollution related to motor vehicle emissions includes: particulate matter, lead, ozone, nitrogen oxides, carbon monoxide, sulfur oxides, smoke, and "haze". Particulate matter is divided into two subcategories, total suspended particulate, and fine particulate. Total suspended particulate is responsible for soiling and reduction in visibility as a contributor to haze, as well as for health problems associated with fine particulate. Fine particulate, less than 10 microns in diameter, are the predominant cause of health effects of particulate matter, since these particles are inhaled deep into the lungs. In addition to the total and fine categorization, particulate is also characterized as primary and secondary. Secondary particulate matter is formed in the atmosphere by chemical reactions among previously emitted gases, such as hydrocarbons, nitrogen oxides, and sulfur dioxide. The estimation of the contribution of motor vehicles to suspended particulate in the atmosphere is therefore not simple, even when the direct contribution of primary particulate from motor vehicle exhaust is known. Motor vehicle exhaust, through both primary and secondary processes, constitutes a much larger share of fine particulate matter than of total suspended particulate.

It is very important to distinguish between engines which typically use gasoline, spark ignited engines, and those which typically use diesel fuel (gasoil/Solar), compression ignition engines. The emissions characteristics of the two types of engines are very different. In Egypt leaded gasoline is currently used in spark ignited engines. Gasoil is used in compression ignition engines. Gasoline contains lead, but Gasoil does not. Gasoil contains sulfur but gasoline does not (except in very small quantities). Gasoline fueled engines emit far more lead, hydrocarbons, and carbon monoxide per unit of fuel used than do diesel fueled engines. Diesel fueled engines emit far more particulate, smoke (as contributor to haze), and sulfur oxides, and somewhat greater nitrogen oxides per unit of fuel used.

The study team sought the best testing laboratories available in Cairo for purposes of developing an emissions baseline for motor vehicles. We visited and viewed two emissions test facilities and had meetings with two other organizations which have engine test facilities used for the purpose of testing power, torque, and fuel consumption of engines which have been built or repaired. We asked other organizations if they had any such facilities. In all appropriate cases of inquiry, our consultations indicated no knowledge of any other *emissions* test facilities. For those two facilities which had emissions test equipment, we found that the emissions which could be measured were limited to carbon monoxide, hydrocarbons, smoke, and carbon dioxide. The equipment used for the tests is, in effect, designed to allow the tester to optimize fuel efficiency. Its purpose is not to estimate emissions in a manner which can be used to predict emissions of vehicles in use in the Cairo fleet. The equipment is useful primarily for comparisons among the same engines and vehicle type, but not for comparisons between engines and vehicle types.

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Hydrocarbon and Ozone Formation

Although there is a desire on the part of the study team to establish a baseline characterization of vehicle emissions by making use of existing test equipment, there was a great deal of concern about the generation of misleading information. In particular, we are concerned that improper comparisons between the emission of natural gas vehicles and current vehicles will be generated. This problem was experienced in the United States, even with highly sophisticated test equipment. Two problems existed for the U.S. natural gas industry. First, the initial conversion technologies were not well executed, and initial results did not reflect the true capabilities of natural gas vehicles, which became clear after the technology was refined. Second, there was a debate with the U.S. Environmental Protection Agency (EPA) concerning the proper measurement of hydrocarbons. This problem is relevant to the Egyptian situation. The U.S. standard for gasoline vehicle hydrocarbon emissions is a "total hydrocarbons" standard. However, it has been recognized that the degree to which hydrocarbons contribute to ozone formation is based on the reactivity of the various hydrocarbons in the atmosphere. The reactivity of a given amount of total hydrocarbons from a natural gas vehicle is far less than for a gasoline vehicle, because most of the natural gas vehicle hydrocarbons are methane, which is not very reactive. The U.S. standard for natural gas vehicles has been rewritten so that only non-methane hydrocarbons count against the hydrocarbon emissions standard. However, the Egyptian facilities that were visited do not have the ability to distinguish between non-methane and methane hydrocarbons. Accordingly, tests from these facilities will be biased against natural gas vehicles, since they will incorrectly treat methane emissions as equivalent in importance to gasoline hydrocarbon emissions with respect to possible ozone formation. The obvious solution to this problem is for Egyptian test facilities to obtain equipment which will allow the speciation (detailed identification of) hydrocarbon emissions.

Particulate

Particulate matter can conceptually be divided into many categories. Total suspended particulate (TSP) has been measured in Cairo (Nasralla, 1990). There is only a little indication in the data collected that the core area of Cairo has a more serious problem than residential areas. Concentrations are generally high and are highest in industrial Helwan, where a cement factory is located. Nevertheless, residential Heliopolis, to the northwest of Cairo, consistently had the lowest ambient TSP count; at 500-600 $\mu g/m^3$ annually for years 1987-89. The World Health Organization (WHO) Standard is 60-90 $\mu g/m^3$. Thus, even at the site with the lowest concentration, TSP has been far above recommended standards.

Black smoke and "white smoke" are two categories of emissions that diesel engineers use when discussing gasoil engine emissions. Black smoke is more readily visible. In U.S. tests designed to measure *fine* particulate in contrast to TSP, two filters are used. The first filter has larger diameter openings than the second. The first captures larger particulate, allowing fine particles to pass through to the second filter, which captures the fine particulate. In a properly operating advanced diesel engine the second filter will remain white, but will nevertheless catch important amounts of fine particulate. Accurate measurement of this fine particulate is challenging. (A paper describing a "dilution tunnel" needed to make accurate measurements of particulate emissions is provided in Appendix ????).

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8.3.3 Selecting appropriate emission factors.

Existing test data, though flawed, suggest that mean emission rates representative of early 1970s U.S. conditions can be used to represent the current contribution of vehicular pollution loading in Greater Cairo. This will, however, overstate the emissions of those vehicles which are well-tuned, as well as those of most late-model cars and trucks. This overstatement is approximately balanced by the fact that Cairo traffic moves in conditions more congested than those assumed in the Federal Test Procedure. However, with respect to the fine (10-micron diameter and less) component of particulate emissions, recent studies have shown that 1970s-era emission factors published by the U.S. EPA that account for the effect of re-suspended road dusts significantly overestimate the contribution of vehicular activity and, consequently, will overpredict the concentration of fine particles if applied to specific street corridors or canyons (Black *et al*, 1983; Balough, Larson, and Mannering, 1993). Although due to lack of data no actual dispersion analysis is being attempted for this study, we would endorse use of Black *et al*'s more recent estimates for fine particle emission rates as a share of (relatively uncontrolled) diesel bus emissions. Exhibit 8.1 summarizes the emission rate set we applied and their comparison with published EPA rates applicable to early-1970s urban diesel buses. PM_{10} values are corrected to eliminate the resuspended component. Our very high SOx value reflects gasoil at 1.5% sulfur weight percent (compared to EPA's assumed 0.2% for U.S diesel fuel) and slightly lower fuel economy for Cairo buses than for EPA's test vehicles, based on data from CTA and GCBC. Also, the EPA factor for hydrocarbons is all-inclusive, not specific to the non-methane fraction; our value includes only non-methane HC.

Exhibit 8.1 Comparison of Published EPA Diesel Bus Emission Rates and Estimated Cairo Values in this Study (g/km)

EMISSION VALUE SOURCE	PM_{10}	Lead	CO	NMHC	NOx	SOx
EPA Pub. no. *AP-42* (1977)*	0.81	--	13.2	2.5	13.4	1.7
References cited this report	0.90	--	13.0	0.5	12.6	14.0

* *Compilation of Air Pollutant Emission Factors* (1977), Section 3: Mobile Sources

8.4 Potential Emissions Reductions

Exhibit 8.2 *conservatively* compares the emissions performance per vehicle of the conversion alternatives presented in this report to the *aging* vehicular propulsion systems they would replace or supplement. For our comparison, it is assumed that dual-fueled vehicles replace heavy diesels only, while dedicated vehicles are candidates to replace either gasoline or diesel propulsion.

We see that, for that portion of the Cairo vehicular fleet subject to conversion, virtually all results are generally in the direction of improvement. The principal exceptions to this, dual-fuel diesel conversion effect on CO and bi-fuel conversion effect on NOx, result in the former case from the loss of combustion efficiency inherent in converting from CI to SI operation and/or a compression ratio not optimal for *either* fuel; and, in the latter case, from gasoline-oriented

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combustion ratios that produce a slightly-enriched higher-temperature environment in the combustion chamber when CNG is being burned. This tends to increase NOx from CNG relative to gasoline combustion even in a poorly-tuned engine.

Exhibit 8.2 Net Change in Per-Vehicle Emissions Attributable to CNG Conversion Options

CONVERSION OPTION	PM_{10}	Lead	CO	NMHC	NOx	SOx
Dual fuel CI--compression ratio unadjusted	-	N/A	●/+	●	●	-
Dual fuel (pilot charge) CI--compression ratio lowered toward CNG optimum)	- -	N/A	●/+ *	●	●	- -
Bi-fuel SI--conversion not optimized for CNG	●	-	-	-	●/+	●
Dedicated (CNG-optimized) CI--diesel baseline	- -	N/A	- -/+ *	-	-	- -
Dedicated SI--gasoline baseline	-	- -	- -/+	- -	●/-	-

KEY:
- - Major emissions reduction
- - Minor emissions reduction
- ●/- No change to slight emissions reduction
- ● No consistent direction of change, if any (Indifferent)
- ●/+ No change to slight emissions increase
- - -/+ Wide variability in results possible, depending on conversion parameters
- N/A Not applicable

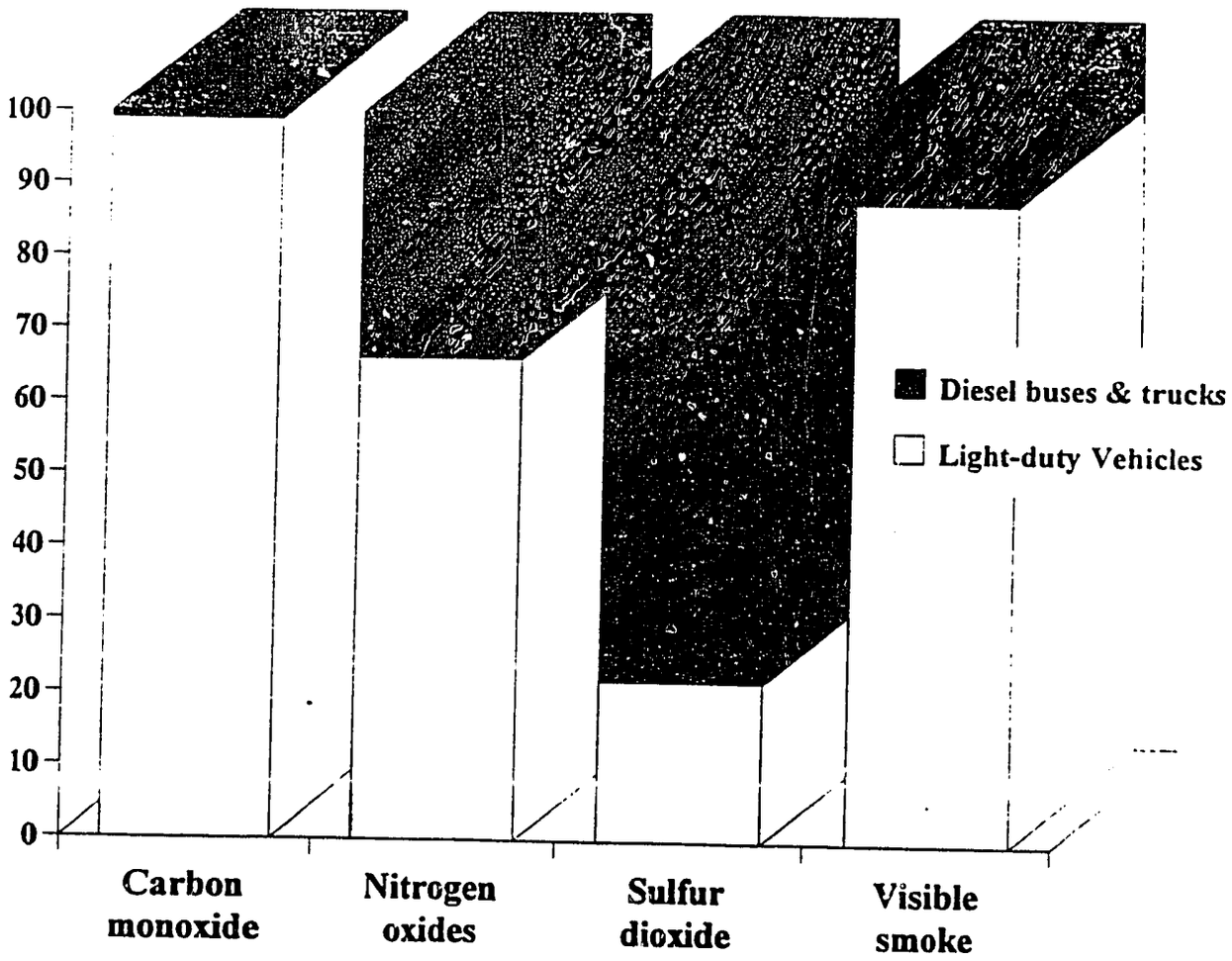
* Assumes retrofit excludes catalytic convertor

8.5 Potential Pollutant Concentration Reductions

Because non-vehicular emission sources contribute significantly to many of the observed pollutant concentrations in Greater Cairo, concentration reduction benefits of CNG conversion will not precisely track the emission reductions shown in Exhibit 8.3

Exhibit 8.3

Percentage contribution to vehicular emissions (Faiz, et. al.[1990]; Nasralla [1990])



Based on the best estimates available to us of contemporary Cairo air pollutant concentrations and their proportional source contributions, as defined in the references cited above, Exhibit 8.3 illustrates the percentage shares of emission loading for four major pollutants attributable to light- and heavy-duty vehicles in Cairo, while Exhibit 8.4 shows expected *concentration* reductions attributable to the conversion strategy alternatives.

Clearly the greatest concentration reduction benefits to be realized in any CNG conversion program that transcends simple dual-fuel retrofit of diesel buses is in the domain of PM_{10} and sulfur oxides, with the potential for modest carbon monoxide reduction a minor secondary benefit.

Exhibit 8.4 Net Expected Change in Cairo's Ambient Pollutant Concentrations Attributable to CNG Conversion Options

CONVERSION OPTION	PM_{10}	Lead	CO	NMHC	NOx	SOx
Dual fuel CI--compression ratio unadjusted	-	N/A	●	●	●	-
Dual fuel (pilot charge) CI--compression ratio lowered toward CNG optimum)	- -	N/A	●	●	●	- -
Bi-fuel SI--conversion not optimized for CNG	●	-	-	-	●/+	●
Dedicated (CNG-optimized) CI--diesel baseline	- -	N/A	●/-	-	-	- -
Dedicated SI--gasoline baseline	-	- -	-	- -	●/-	-

KEY:
- - - Average localized concentration reduction > 3%
- - Localized concentration reduction 3% - 5%
- ● No systematic change in average localized concentration
- + Potential for localized concentration increase
- N/A Not applicable

8.6 Potential Health Benefits

The interaction of pollutants with biological molecules, or receptors, triggers mechanisms of toxic response. But even today these mechanisms are poorly understood due to their complexity and reliance on the presence of other factors. Simple measurement of exposure, the path of a pollutant to its uptake by a receptor, cannot be directly used for many biological problems. Also, the sensitivity of any individual to the toxic effects of a pollutant depends on many other conditions (genetics, nutrition, availability of inhibitors in the body) that are not measured at the time of exposure (Bates & Watson, 1988). Thus, virtually all analyses in the area of specific health insults of mobile source pollution, and health benefits of its mitigation, are extrapolations and are associated with a rather low degree of confidence.

8.6.1 Fine particulate matter

The fate of particle macrophages reaching pulmonary areas is either (a) removal via the bronchial mucociliary system (the vast majority) or (b) translocation into the bloodstream or lymphatic system from the interstitium through the alveolar capillary endothelium. For organic compounds associated with (resident upon) particles in the latter category, antigen may be translated to the lung-associated lymph nodes where there is often a direct effect on the lymphoid cells in these tissues. Toxicants among these compounds, such as benzene and benzo-a-pyrene, kill macrophages or inhibit phagocytosis, which diminishes the capacity of the lung to clear antigen to the lymphatic system. Thus, for example, average residence time in bronchial tissue of insoluble particles derived from cigarette smoke is 3 to 5 months (Schlesinger, 1988; Sun, Bond & Dahl, 1988).

Few unflawed efforts to quantify the carcinogenesis of diesel exhaust have been made, and virtually all of them are extrapolations from data developed about exposure to other organic extractable materials (cigarette smoke, roofing tar, etc.). A study in the early 1980s developed an extrapolated estimate of 0.2 to 0.6 X 10^{-4} lung cancers per microgram of exhaust particulate per cubic meter of air (average annual concentration) (Albert *et al*, 1983; Lewtas, Nesnow & Albert, 1983). The process of carcinoma formation results from chemical modification of DNA by the invasive organic. Despite the almost impossible task of separating their effects from other carcinogens present in exhausts, evidence points strongly to polynuclear aromatic hydrocarbons as being carcinogenic to humans via both proximate and ultimate interactions as metabolites on the pathway to DNA reaction and with DNA itself.

In Greater Cairo there are at least three major confounding factors rendering any effort to identify specific health consequences of fine particulate very uncertain, especially that emitted by diesel buses and other heavy-duty vehicles. The first is the surrounding desert environment itself and its high loading of respirable particulate matter, which combines with major anthropogenic sources such as the Shoubra El-Khaima industrial complex and the Helwan cement plant to produce a particulate matter loading (and depositional volume) which is formidable even in the absence of diesel vehicles. The second is the high incidence of smoking among Cairo residents. In Emara (1987), over 30 percent of CTA garage workers were "heavy" (>2 packs a day) smokers; this figure may or may not be representative of the general populace, but the statistic provides evidence of daily exposure to at least secondhand cigarette smoke by a substantial fraction of Cairenes. The third factor is the recent population growth of Greater Cairo itself, much of which is accounted for by a large influx from other parts of Egypt and the Arab world. When these immigrants develop impaired respiratory health or cancers after taking up residency in Cairo, the principal contributing cause could be the character of pollutant exposure they experienced prior to arrival in Cairo.

Chemical mass balance studies have shown that re-entrainment of road dust, even in urban areas with most of their streets paved, is substantially underestimated as a contributor to TSP, and can account for over 50 percent of the aerosol at a given location. In one oft-cited study, motor vehicle exhaust, while remaining approximately constant in total mass computation, dropped from about 15 percent to less than 7 percent of the particulate (aerosol) inventory following source apportionment (Core, Hanrahan & Cooper, 1988; Wittorff *et al*, 1994). This is not

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inconsistent with the 1987 finding reported by Dr. J. Borrazzo in a May 5, 1994 report to USAID/Cairo that public transportation accounts for about 14 percent of Cairo particulate *not including natural sources*. Applying size distribution data from Black *et al*, we deduce a PM_{10} constituent of about 5 percent by mass of particulate concentrations in urban streets. However, because diesel fuel combustion in Greater Cairo represents a much higher share of transportation activity than the cities from which our apportionment data derive, the correspondingly larger amount of dust and stationary source particulate is at least partially offset with respect to the Core findings. Also, as discussed above, measurements of black smoke concentrations in Cairo represent a reasonably reliable indication of the presence of engine combustion by diesel vehicles. We conservatively assume that diesel vehicle-generated particulate (with resident carcinogens) represents 10 percent of the daytime particulate concentration in the breathing space of heavily-trafficked Cairo streets. Thus, of the ambient TSP concentrations reported (through 1989) for high traffic areas in Ali, Nasralla & Shakour (1986), values are generally in excess of 600 $\mu g/m^3$, and the density of the diesel-emitted component is from 60 to 70 $\mu g/m^3$, of which about 90 percent is of 10 microns or less in diameter. If the cited 1983 results of Albert, Lewtas and colleagues are accurate, this means that diesels account for between 11 and 63 of every 10,000 lung cancers in Greater Cairo. Public transit buses, roughly 40 percent of the diesel bus population, contribute about 25 percent of the daytime loading of total diesel particulate in the more congested areas (considering daily activity patterns). This share would drop to between 5 and 15 percent after retrofit depending on the option selected. Thus, conversion to natural gas could presumably (in the absence of the confuting factors cited above) eliminate between 1 and 10 latent cancer fatalities out of every 10,000 per year among *longtime* Cairo inhabitants. Exhibit 8.4 traces these relationships.

Exhibit 8.4 Scaling of Transit Bus Conversion Strategy to Mitigation of Latent Cancer Fatalities (LCFs) Assuming No Pre-Existing Condition

TRANSIT BUS CONVERSION TYPE	RESULTING DAYTIME PM_{10} CONCENTRATION RANGE ($\mu g/m^3$)	REDUCTION IN AVERAGE PM_{10} EXPOSURE IN CENTRAL CAIRO ($\mu g/m^3$)	RANGE OF REDUCTION IN LCFs per 10,000 (Albert, Lewtas *et al*, 1983)
Dual Fuel CI (no change to compression ratio)	> 600	4 - 7	1 - 4
Pilot-injection Natural Gas (lowered compression ratio)	590 - 600	8 - 12	2 - 7
Dedicated CNG Retrofit	585 - 595	10 - 14	2 - 8
New CNG Engine	580 - 590	13 - 16	3 - 10

8.6.2 Lead

Both the findings of Core, Hanrahan, and Cooper (1988) regarding the understatement of the contribution of road dust to the particle loading of urban air, and the known persistence of such dusts in Cairo streets, lend a special urgency to the goal of mitigating traffic-borne lead by significantly reducing its concentration in motor gasolines. However, reducing the quantity of lead in gasoline will not result in an immediate and substantial reduction of its mass in road dust (as a heavy component of dustfall, it is likely to resist mechanical mobilization). Nor will it result in a near-term reduction in average blood lead levels commensurate with its change as a component of motor fuel because lead persists in ingestion pathways (for example, in the food tins soldiers use for food tins and it is still coming out of Helwan smelters). Exhibit 8.6 shows the expected changes in fuel lead, emission rate, and blood lead due to a) the planned 1995 reduction in lead mass percent of gasoline and b) the incremental effect of a light-duty spark ignition bi-fuel retrofit strategy, assuming 33% of light-duty vehicle-kilometers of travel at any given time is operating on CNG. (A similar CNG vehicle penetration analysis conducted by EgyptGas held, and we accept, that rate of retrofit could keep up with fleet/activity growth.) The blood lead result is based on application of the inverse of a relationship described in Angle (1984) to the estimated baseline ambient lead concentrations in central and inner residential areas reported by Ali, *et al* (1986). In both cases, assuming controls will be continued and expanded for at least 10 years, blood lead for all but the most chronically exposed Cairenes should *eventually* drop below the WHO health guideline of 20 μg/dl (which is still above average U.S. levels of 4 to 5 μg/dl).

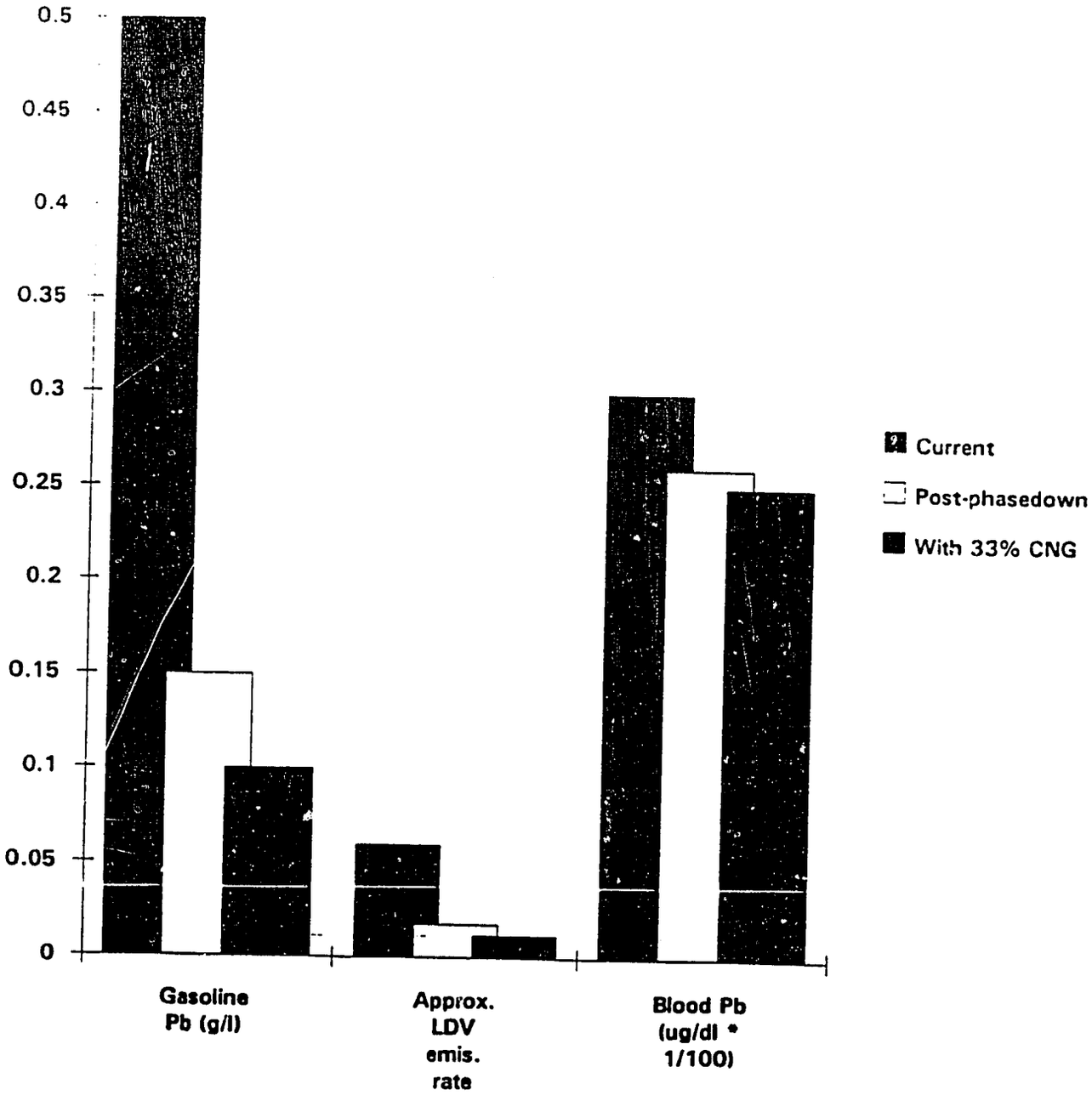
8.6.3 Carbon monoxide

The findings of Emara (1987) and Nasralla (1991) concerning blood carboxyhemoglobin levels of policemen, garage workers and bus drivers in Greater Cairo suggest that modest mitigation of this health threat to the most directly-exposed segments of the population can be achieved by conversion of public buses to *dedicated* CNG. However, since Faiz, *et al* (1990, cf. Fig. 1) reports that these buses now account for less than 1 percent of mobile-source CO emissions area wide, average carboxyhemoglobin levels would not be affected.

8.6.4 Ozone

Because excursions of WHO and U.S. ambient ozone standards have not yet been observed in Cairo, as measured by modern state-of-the-art equipment (although available measurements did approach these standards), no ozone exposure reduction health benefit will be attributed to any of the CNG conversion strategies. However, poorly accomplished CNG conversions are known to have increased levels of NMHC emissions. In addition to the importance of developing and using advanced test facilities to assure that CNG conversions actually reduce NMHC, it will be extremely important to assign high priority to maintenance of low gasoline volatility in the selection of octane-enhancing additives to replace lead. Further growth in gasoline use and/or increased gasoline volatility are very likely to produce ozone violations in the future.

Exhibit 8.6 Estimated Effects of Gasoline Pb Reduction Strategies



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8.7 Non-Quantifiable Benefits

8.7.1 SO_2/sulfate and nitrate exposure of garage workers

Exposure to sulfur dioxide and sulfates from diesel fuel combustion in vehicles has not been identified as a health hazard to the general public in concentrations normally experienced in ambient air where major stationary sources are not contributing. However, because of the relatively high sulfur content of gasoil and the proximity of bus garage workers to operating diesel engines, respiratory irritation and possible damage due to conversion of these compounds to acids in breathing passages cannot be ruled out for these workers (Bates and Watson, 1988). Thus, removal of one source of such insult (sulfur compounds in fuel combustion products) may result in a lessening of workplace-specific exposures. If irritation and damage to workers is also, or even primarily, attributable to attack by conversion of nitrogen oxides/nitrates to nitric/nitrous acids in the bronchio-pulmonary system, it is less certain that conversion will result in net benefit.

8.7.2 Sulfate degradation of historic monuments

Dry deposition of sulfates and nitrates on limestone monuments and their subsequent chemical attack on the limestone surfaces, transforming calcium carbonate to calcium sulfate or nitrate (after their own conversion by ambient moisture to mild sulfuric and nitric acid), will be a problem in Cairo as long as sulfur-bearing fuels are burned in stationary or mobile sources. Replacement of gasoil by CNG in buses will mitigate at least a small portion of this slow destruction.

8.7.3 Visibility and soiling

Balogh, Larson and Mannering (1993) cite several studies that have established a high and direct correlation between diesel vehicular traffic and soiling of adjacent structures. Thus, the almost complete elimination of soot output by bus operation due to CNG conversion should result in a commensurate reduction in soiling of structures adjacent to the roadway. However, because Faiz, *et al* (1990) attribute over 80 percent of smoke emissions from Cairo mobile sources to *cars, motorcycles, and other light-duty vehicles*, this reduction may not be substantial.

Section 9.0 Institutional Requirements

9.1 Introduction

Safe and effective implementation of an aggressive program of conversion to CNG as a transportation fuel will require the well planned, highly coordinated and broad-based effort of several Egyptian Ministries and other public, parastatal, and non-governmental groups. Part of the scope of this feasibility study is an initial assessment of the institutional requirements associated with the implementation of a CNG conversion program. This assessment includes identifying functions and activities, and evaluating the approximate magnitude of the effort that would be required. It does not include recommending specific roles for individual organizations. Assignment of roles will be the responsibility of others as the program develops. Nonetheless, a brief overview of organizations currently active or investigating CNG use is provided.

9.2 Institutional Functions

Broad categories of functions and activities required in the program are briefly described in the following table along with initial assessments of the magnitude of the level of effort in terms of new personnel for each function. In many cases, the function can be performed within the existing capacity of the potential implementing agencies. The estimates of level of effort do not include any USAID or USAID contractor effort to implement the program, such as technical assistance, training, or commodity procurement. They include only Egyptian institutional requirements to implement the initial CNG fleet conversions. If CNG use expands to include many private passenger cars or other fleets, then these institutional requirements will also expand. However, by that time the knowledge gained through initial CNG fleet activities will provide an adequate basis for rational growth in the institutional structure. An initial estimate is that the implementation of CNG operations in the public bus fleet only, not to expand CNG use elsewhere, will involve approximately 50 new positions across all organizations. The cost of these added personnel that could be attributed to the bus fleet conversions is estimated to be 50 persons times 600 L.E. times 12 months = 360,000 L.E. per year. It is likely that much of this could be made up by reassigning individuals from other operations and increasing organizational efficiency.

Exhibit 9.1 Institutional Functions Associated with a CTA Bus Fleet Conversion

FUNCTION	MAGNITUDE OF EFFORT
Overall Program Planning, Coordination and Evaluation. The CNG program will have multiple components that must be carefully planned and managed.	The program must have a lead organization and staffing should include a Program Supervisor/ Coordinator, engineer, financial analyst, and support staff. This group could also actively pursue methods of expanding CNG use in other fleets. A Steering Committee should provide oversight and direction. See below for recommendation on the Steering Committee.
Coordination with Transportation Requirements. The CNG Program must be continuously coordinated with the overall operational requirements and budgetary constraints of the participating fleets and Cairo's transportation requirements.	Each fleet should have a CNG Program Supervisor/Coordinator.
Coordination with Natural Gas Supply System. All planning for the CNG program and individual stations must be coordinated within the context of the overall gas supply and distribution system.	This activity will in general fit within the existing institutional capacity. Assignment of an engineer trained in the requirements of CNG programs is appropriate.
Physical Connection to the Natural Gas Supply System	This activity will in general fit within the existing capabilities for gas distribution. The assignment of an engineer trained in the special requirements of CNG stations may be approoriate.
Establishment of Safety Standards. Safety standards do exist in Egypt for CNG cylinders for use in military applications and Egypt Gas is responsible for their enforcement. During the engineering phase of a CNG program, these standards should be reviewed for completeness, enforceability, and appropriateness to public and private vehicles. Standards for other CNG components and activities are also needed.	Establishment of standards can occur within the existing framework for standards development in Egypt with Technical Assistance provided by USAID and oversight by the CNG Steering Committee.
Establishment of Safety Regulations, Licensing and Certification Procedures. Laws and regulations must be developed and implemented that permit the strong enforcement of new standards.	The development of regulations can be led by a CNG Steering Committee, discussed in this section.

FUNCTION	MAGNITUDE OF EFFORT
Initial and Periodic Inspection of Vehicles. Enforcement of safety regulations will require vehicle inspections by knowledgeable technicians backed by stern penalties and authority.	A team of approximately 4 well trained inspectors should be adequate for the CTA fleet and would provide a core of experienced personnel for training of other inspectors as CNG use spreads.
Initial and Periodic Inspection of Stations to enforce safety regulations.	A team of approximately 2 well trained inspectors should be adequate for the CTA fleet.
Conduct of Air Quality and Transportation Research. The impact of CNG use on Cairo air quality and operation of the transportation sector must be evaluated.	The extent of this work and the proportion to be performed within Egyptian institutions is difficult to determine at this time.
Conduct of Emissions Testing. No adequate facilities exist for complete measurement of vehicular emissions in Egypt.	The requirements for an emissions laboratory are described separately in this section. Approximately 8 technicians and engineers would be required to staff the facility. Depending on the facility chosen, most of these could be existing personnel.
Development of a Public Awareness/Information Campaign. Safety of CNG is a serious concern to the public and officials in Egypt. A significant public relations effort should precede full scale operation to assure the public of the fuel's safety.	See below for an estimate of public awareness campaign program requirements. One Public Information Campaign Coordinator may be appropriate with a budget for mass media presentation material development.
Publish Program Reports. As a method to encourage use of CNG, monthly, quarterly, and annual progress reports, and financial and technical reports should be published and disseminated widely.	A team of 4 trained in Desktop Publishing and the fundamentals of CNG use should be adequate for publication purposes.
Implementation of a Broad Training Program. Safe operation will require thoroughly trained technicians, engineers, and operators.	See below for a discussion of training requirements. A Training Coordinator will be required.
Evaluation of Acceptance by Participants. The reactions of all groups and important individuals must be evaluated early in the program to assess required corrections and general levels of satisfaction. Passengers, drivers, technicians and others should be included.	A team of approximately two is needed during the pilot and implementation phases, but probably not on a continuous basis.

FUNCTION	MAGNITUDE OF EFFORT
Conduct of CNG Vehicle Feasibility Studies for Other Fleets. One intent of the program is to encourage broader use of CNG. If, as expected, the initial fleets create enthusiasm for CNG use, it will be important to ensure that individuals considering adopting the technology later have access to required expertise. A team of engineers and economists who have been trained to conduct feasibility studies is needed.	A team of approximately 8 engineers and economists/financial analysts should be adequate. These individuals should be most highly trained and should also be able to train others.
Coordination and Support of Industries for Local Manufacture of CNG System Components. Early positive results from the program may encourage the government of Egypt or the private sector to pursue local manufacture of CNG components or vehicles.	The effort associated with manufacturing will depend on the degree to which local manufacturing is pursued and cannot be estimated at this time. Costs for local manufacture are assumed at this stage to be equivalent to foreign manufacture costs which are included in the equipment component of economic analysis.
Physical Conversion of Vehicles. Governmental or parastatal organizations may become involved in actually converting vehicles. Use of the private sector to the maximum possible extent is recommended.	Costs associated with this activity are included in the labor costs listed in the economic analysis and are not treated separately.
Operation of Filling Stations. Governmental or para-statal organizations may become involved in ownership and operation of CNG filling stations.	Costs associated with filling station operation are assumed to be included in the cost of the CNG charged to the fleet owner.
CNG Fleet Operation. The participating fleet owner will incur expenses associated with running the CNG vehicles, maintaining them, fueling, etc.	These added costs have been included in the technical component of the economic analysis of this study.

The generic functions outlined in the above table must be expanded during the project development stage to address detailed requirements. These responsibilities must be assigned to specific groups in a carefully structured, comprehensive overall plan to ensure a successful project. Examples of detailed responsibilities to be assigned include:

- Assure adequate and uninterrupted supply of natural gas on a long term basis for filling stations.
- Establish and enforce specifications and standards for CNG cylinders, storage cascades, and dispensers. Test and license storage cylinders, cascades, and connectors.
- Plan expansion of CNG to other users.
- Export gasoil saved by switching to CNG

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- Extend 30 bar main line to CTA garage when needed.
- Seek national and international donors for project grants.
- Prepare tender, advertise, and receive bids, select contractors for filling stations, cylinders, cascades, dispensers, etc.
- Explore opportunities for local manufacture of cylinders.
- Select CTA garage for pilot vehicles.
- Identify representative buses for initial CTA pilot.
- Plan and implement scheduled and emergency service and maintenance of CNG vehicles.
- Keep records of slow and fast fill times, distance travelled per day, duration of parking at garage, fuel economy, etc.

9.3. Potential Participating Organizations

Because of its broad responsibilities in the supply of natural gas in Egypt, **the Ministry of Petroleum** must play a central role in developing and implementing the program. **PETROBEL and GUPCO** are directly affiliated with the Ministry of Petroleum. Through the Ministry of Petroleum other institutions will also be involved. The **Organization for Energy Conservation & Planning (OECP)** is also under the Minister of Petroleum. According to Dr. Ibrahim Abdel Gelil, Chairman of OECP, his organization has been designated by the Ministry of Petroleum to be the "Egyptian counterpart" representing the GOE on CNG/transportation related activities, to be the interface of the High Committee on CNG with USAID, and to provide technical assistance to that committee for developing an integrated CNG program in Egypt. **Egypt Gas** is responsible for the natural gas distribution lines in the country. According to Law No: 217, Egypt Gas is also charged with establishing procedures for testing CNG cylinders and for certifying CNG cylinders that pass the test. Another organization within the Ministry of Petroleum is **Misr Petroleum Company Laboratory** which has an auto emission testing facility and a chassis dynamometer for testing buses and cars.

Other groups that may be involved in the implementation of a CNG conversion program are the two bus operating companies: **The Cairo Transit Authority (CTA) and The Greater Cairo Bus Company (GCBC)**. These bus companies are responsible for operating and maintaining a significant part of Cairo's bus service for the public. They have several garages that are widely distributed throughout the city. Some garages are located close to high pressure natural gas pipelines. Hence fast filling stations could be located at or near strategically placed garages. The Gesr El Suez CTA Garage is an engine overhaul and bus repair shop that has an adequate number of engine testing bays. It could be a site for the assembly of reconditioned CNG engines in Egypt.

A third group will be the **Egyptian Environment Affairs Agency (EEAA)**. Its role could be to receive and publish auto emission data from the tests that will be run on diesel bus engines and converted CNG bus engines. The bus engine emission tests may be run on the chassis dynamometer at Misr Laboratories. The diesel and CNG engine tests may be performed at Cairo University or at the engine test bays of the Gesr El Suez CTA Garage.

Key representatives from the three groups may form the **Steering Committee** to establish general policies for project implementation, budgets, task forces, and implementation schedules. The Minister of Petroleum has already formed a CNG Steering Committee that consists of representatives of some of the above mentioned organizations. The existing committee's directive is to explore ways of increasing CNG use in vehicles in Egypt. The Steering Committee for the project aimed at a specific fleet could replace, be a modification of, subset of, or an addition to the existing broader-scope Steering Committee.

Assuming success of the early phases of a CNG program, the next stage will be the manufacture or assembly of new or reconditioned natural gas engines in Egypt. For this task, the companies such as **The El-Nasr Automotive Manufacturing Company (NASCO), CTA, and GCBC** representing the public sector or **Carlin Middle East, Ghabor, Isuzu, and Ghorica,** representing the private sector may be participants. The Minister of Industry may play a role in this activity as well. A number of the industrial firms mentioned are known to be investigating the potential for manufacturing components or assembling CNG vehicles.

9.4. Training and Public Awareness Requirements

The groups of individuals within the functional activity areas should receive various types of training on different subjects and at different levels of detail. The following chart illustrates a conceptual training plan to illustrate the general magnitude of the required training program. Note that the numbers of individuals listed in Exhibit 9.2 as receiving training do not necessarily agree with the number of individuals indicated in the table of Exhibit 9.1 above. In some cases, this is due to training of trainers. Also, the numbers listed in Exhibit 9.2 do not imply new employees in all cases. For instance, the number of people trained in CNG fleet operations is large primarily to address safety concerns and basic CNG considerations. Not all of this training can be counted against the initial fleets, because the intent of much of the training should be to provide a solid foundation of experienced personnel for expanding into other fleets.

Exhibit 9.2 Conceptual Training Program by Functional Area

FUNCTION	BROAD CATEGORY OF TRAINING COURSE					
	TOTAL PERSONS TRAINED	INTRO TO CNG TECHNOLOGY & SAFETY	EQUIPMENT OPERATION	CNG ECONOMIC ANALYSIS	DETAILED ENGINEERING/ MANUFACTURING	TOURS OF OTHER FLEETS
LEAD AGENCY	3	3	3	3	2	1
STEERING COMMITTEE	15	15	3	3	2	4
FLEET COORDINATOR	1	1	1	1	1	1
GAS SUPPLY COORDINATOR	2	2	2	1	2	1
GAS CONNECTIONS	2	2	2		2	

FUNCTION	BROAD CATEGORY OF TRAINING COURSE					
	TOTAL PERSONS TRAINED	INTRO TO CNG TECHNOLOGY & SAFETY	EQUIPMENT OPERATION	CNG ECONOMIC ANALYSIS	DETAILED ENGINEERING/ MANUFACTURING	TOURS OF OTHER FLEETS
VEHICLE INSPECTORS	4	4	4		4	
STATION INSPECTORS	2	2	2		2	
RESEARCH	10	10	10	10	10	
EMISSIONS TESTING	8	8	8		8	2
PUBLIC AWARENESS	2	2	2	2		
PUBLICATIONS	4	2				
TRAINING	8	8	8	8	8	8
ACCEPTANCE EVALUATION	2	2				
FEASIBILITY STUDIES	8	8	8	8	8	8
MANUFACTURING	8	8	8	8	8	
VEHICLE CONVERSIONS	10	10	10		10	
STATION OPERATIONS	50	50	50			
FLEET OPERATION	50	50	50	5	5	
DRIVERS	3000	3000	3000			

Note that in the training table, each column may involve several different courses aimed at different groups. For instance, the publishers will receive equipment training in Desktop Publishing and the Emissions Testing personnel will receive equipment operations training in CNG vehicles and emissions measurement equipment and procedures. Personnel on the Steering Committee and within the lead agency should receive training in engineering/economic policy analysis associated with CNG.

For national and public acceptance of natural gas as a transportation fuel for buses, pick-up trucks, and fleet passenger vehicles, a massive public awareness campaign has to be mounted highlighting the following topics:

- The safety and warranty features of available CNG conversion technologies and CNG engines. Of particular interest is the safety and warranty features of CNG cylinders carried on board the vehicles.

- The economic benefits of converting from diesel or gasoline engines to CNG engines in

Cairo and the appropriate CNG conversion technology for each type of fleet vehicle engine; the economic benefits of the CNG Conversion Program should be assessed from the national and individual vehicle owner's and filling station operator's perspectives; and

- The State-of-the-Art natural gas technology best suited for CNG vehicle conversions for Cairo. Discussion of the appropriate CNG conversion technology for Cairo should take into consideration the condition of the vehicles and the quality of the servicing, repair and maintenance programs available.

The public awareness campaign should be closely tied to the Training Program and the Publishing efforts. A Public Campaign Coordinator will be needed. Some funding for development of TV spots or newspaper articles will be needed but are not estimated here.

9.5. Emissions Testing

Converted vehicles are expected to demonstrate an improvement in emission characteristics. Because natural gas is a clean fuel, it is generally accepted that the pollution from auto emissions will be reduced. However, an Auto Emission Testing and Standards Facility for Egypt is recommended to monitor and document the reduction in pollution for natural gas engines. This facility can also be used for development of emissions standards for all vehicles and other air quality related research.

Information on air quality in Cairo is limited in many respects, while information on emissions from motor vehicles is nonexistent for several pollutants and very crude for others. The study team sought the best testing laboratories available in Cairo for purposes of developing an emissions baseline for motor vehicles. We visited and viewed two emissions test facilities and had meetings with two other organizations which have engine test facilities used for the purpose of testing power, torque, and fuel consumption of engines which have been built or repaired. We asked other organizations if they had any such facilities. In all appropriate cases of inquiry, our consultations indicated no knowledge of any other emissions test facilities. For those two facilities which had emissions test equipment, we found that the emissions which could be measured were limited to carbon monoxide, hydrocarbons, smoke, and carbon dioxide. The equipment used for the tests is, in effect, designed to allow the tester to optimize fuel efficiency. Its purpose is not to estimate emissions in a manner which can be used to predict in-use emissions of vehicles in the Cairo fleet. The equipment is useful primarily for comparisons among the same engines and vehicle type, but not for comparisons between engines and vehicle types.

The Egyptian facilities that were visited do not have the ability to distinguish between non-methane and methane hydrocarbons. Accordingly, tests from these facilities will be biased against natural gas vehicles, since they will incorrectly treat methane emissions as equivalent in importance to gasoline hydrocarbon emissions with respect to possible ozone formation. The obvious solution to this problem is for Egyptian test facilities to obtain equipment which will allow the speciation (detailed identification) of hydrocarbon emissions.

BEST AVAILABLE DOCUMENT

9.5.1 Facilities

Accurate measurement of emissions requires that the chassis dynamometer be located in an air conditioned room with temperature controlled very accurately. A separate room for instrumentation and test personnel should be provided. Means should be provided for removal of vehicle exhaust and the test room should be soundproofed.

The light-duty vehicles fueled with gasoline or CNG fuel will be tested on a chassis dynamometer based on a typical time vs. vehicle speed (km/hr) duty cycle. Initially, the cycle used in the U.S. federal test procedure could be used. Simultaneously, efforts should begin to construct an Egyptian duty cycle more representative of local traffic conditions. The existing test facility should be upgraded with NOx, CO, HC, and CO2 instruments and an adjoining chemistry laboratory to analyze exhaust samples. Automation of testing with personal computers will require considerable work and training.

On the heavy-duty vehicle side, it is preferable to follow the standards and procedures that have been set up in the U.S. for testing. The acceptable emissions standards should be Egypt-specific, but the procedures could be easily adapted from the U.S. EPA. A mini-dilution tunnel for particulate measurement and NOx measurement equipment would be needed in addition to the types of equipment already available in-country.

9.5.2 Personnel

Approximately eight technicians, scientists, and engineers should be thoroughly trained in all aspects of emissions measurement and vehicular emissions characteristics.

9.6. Relevant Egyptian Air Quality Monitoring, Research, Standards, and Enforcement Organizations

Currently, several ministries and government agencies are responsible for different aspects of air quality monitoring, standards and enforcement. We provide here a brief listing of a number of public, private and non-governmental groups involved in each activity. This listing is not intended to be comprehensive and no implications of importance should be assumed from the order of presentation:

Academy of Scientific Research and Technologies. The academy comprises thirteen disciplinary councils and four interdisciplinary divisions. It has a membership of approximately 1600 scientists and experts. The Environmental Research Council is concerned with the formulation and execution of a national program for environment-related research and studies, the effects of production practices on the environment as well as proposing appropriate technologies for avoiding environmental hazards, preserving the eco-systems and rationalizing the use of natural resources.

National Research Council. The National Research Council is a center for basic and applied scientific research. It comprises 15 disciplinary research branches including an Environmental Research Branch. Some of its activities are connected with the Air Pollution Laboratory determining the levels of air pollution in the industrial sites, and studying the sources of pollution and control methods.

Petroleum Research Institute. The Petroleum Research Institute provides the national petroleum industry with technical and applied research. It has undertaken important research in treating the harmful effects of oil pollution.

Metals Research and Development Center. This Center contributes by developing air and solid wastes projects to control air pollution sources.

Environmental & Occupational Health Center. This Center is active in the field of environmental monitoring of air, water and soil. It establishes standards of environmental pollutants in collaboration with others.

Public Health Institute, University of Alexandria. It undertakes applied research for raising the standard of public health by combating environmental pollution from chemicals.

General Organization for Industrialization (GOFI). GOFI is the focal point for study of industrial processes in the Ministry of Industry. Inside the organization, a general administration for environmental protection was established in 1978. The Organization contributes in the field of environment by carrying out several projects in water protection, air protection, etc.,

Egyptian Environmental Affairs Agency. The Egyptian Environment Affairs Agency (EEAA) was established by Presidential Decree No: 631 in 1982 to form the link between the Cabinet of Ministers, the different ministries and other bodies concerned with protecting the environment. It is charged with the implementation of environmental programs and plans. EEAA prepares the national plan for environmental studies and drafts environmental legislation. EEAA is responsible for studying and proposing specifications of standards to ensure the protection of citizens from the dangers of environmental pollution.

Some of the environmental projects undertaken by the Technical Office of EEAA are:

- Air protection against pollution and noise
- Protection from wastes, noise and toxic substances
- Set up of a data base for natural environment
- Drafting the National Five Year Environmental Plan

EEAA works with the Ministry of Health and some governorates to support a national environmental monitoring network for air and water pollution.

9.7. Relevant Existing Laws

A number of laws are on the books in Egypt to protect air quality. Listed below are some of the relevant national laws approved by the Legislature:

- Presidential Decree No: 864-1969 establishing the Supreme Committee to protect ambient air against pollution;

- Minister of Health Decree No: 470-1971 establishing standards for ambient and work place air. This decree was later amended by Minister of Health Decree No: 240-1979;

- Law No: 66-1973 concerning traffic, later amended by Laws No: 210-1980 and 20-1983. Minister of Interior Decree No: 291-1974 later amended by Decree No: 407 1983. Chapter V of the law deals with traffic rules concerning vehicle exhaust and forbids heavy smoke.

- Law No: 137-1981 and Decree No: 55-1983 by the Minister of Manpower for implementing this law. These laws determine the amount of fresh air per person in the work place, suitable temperature and humidity.

The Egyptian Government proposed to the Parliament three separate laws one for clean air, one for unpolluted marine water; and the last an overall code for the environment. The Peoples Assembly decided to combine the three proposals into one Unified Code for the Environment.

EEAA has overall responsibility for monitoring ambient air quality and establishing auto emission standards. However, according to the Presidential and Ministerial Decrees, there are several ministries, institutions and a maze of linkages involved in monitoring air quality, setting standards and seeking compliance. Due to the overlapping of functions and poor oversight, the total effort from the gathering of reliable auto emission data to the establishment and enforcement of air pollution standards has been ineffective to date.

See Section 5 of this report for a discussion of safety-related laws.

Section 10.0 Conclusions and Recommendations

Given the stated assumptions, the CNG conversion of the CTA bus fleet is highly cost effective for all options investigated. The best option from both economic, financial, and technical standpoints is the use of new, dedicated CNG buses and engines when new buses and engines are normally scheduled to be purchased. These have the highest benefit to cost ratio and the most certain technical performance. With the typical new bus purchase of about 150 buses per year, and estimating new engine purchases at about 300 per year, the entire fleet of about 2300 normally in-service buses could be changed over in four to five years.

Dedicated retrofits of the existing engines are the next best option, again from the economic, technical, and performance standpoints. Open loop controlled dual fuel retrofits of the existing engines are economically viable but the poorest option. Power loss associated with this option without turbochargering may be unacceptable to the fleet operators. The duel fuel option is poorest from the emission standpoint as well, because diesel fuel is used during starting and idling, when particulate emissions are heavy. The closed loop controlled option is a type of dual fuel approach that is more expensive than the conventional, open loop controlled, dual fuel approach, but the power can be maintained. The benefit/cost ratio of the closed loop controlled dual fuel option is also higher than the conventional dual fuel option. More engineering time and a longer pilot phase will be required wither either dual fuel approach.

Capital cost: The analyses were performed for an "average" CTA garage using 220 serviceable buses, 176 of which operate at the station on an average day. Some of the remaining buses sit in active service, others are in the shop for repairs. Proportioning the costs for those buses, to convert the entire CTA fleet of active buses would require approximately L.E. 128 million, to be scheduled over a five year period.

For fleets which use a lot of fuel, the station design which uses a large compressor bank running simultaneously with the refilling of the vehicles is superior to one in which a smaller compressor bank runs most of the day to fill a storage system which then fills the vehicles.

The CNG conversion of the delivery truck fleet is marginally economical. Internal rates of return for the base case options investigated varied from one to twelve percent. The order of preference for conversion options is essentially the same as for buses, with new trucks and new engines being better than dual fuel retrofit of the old engines. An interesting option to significantly improve the viability of the Cairo Beverage and Industrial Company's CNG conversion program is to permit them to use the existing PETROBEL station located nearby. Of course, numerous organizational and logistic issues would have to be worked out between the public and the private sector companies.

Light duty gasoline vehicle conversions are not economical, except in the case where an existing station exists to serve another fleet. For instance, CTA stations, if used soley for the CTA, would be essentially idle during the daytime. An affiliated passenger car or light truck fleet could be converted economically, if it can use the same refueling station during the day.

The institutional requirements of a CNG conversion program were investigated and quantified. Most of the functions required to achieve conversion of a large fleet in Cairo can be accomplished within the existing capacity of associated organizations. It has been estimated that approximately 50 new positions would be required, but many of these could be filled by reorganizing existing functions.

The environmental benefits of a conversion of the CTA bus fleet were investigated. There is no continuous, quality-assured ambient air monitoring network in place in Greater Cairo for the full range of mobile-source related pollutants. Continuously reliable performance has not been certified for the fixed monitors for SO_2, TSP and black smoke that were in place as of 1992 at eight locations in Greater Cairo (WHO/UNEP, 1992), a fact substantiated in discussion with Dr. M.M. Nasralla of the Air Pollution Department of the National Research Centre (Nasralla, 1994). Reliable information about levels of air pollutants around Greater Cairo is either anecdotal (one-time measurements taken at irregular intervals over a multi-year period predominantly using mobile sampling equipment) (El Kotb & Borman, 1987), or derives from special studies conducted for individual major point sources (e.g., the Shoubra el-Khaima electricity generating station). There is no mobile-source emissions inventory for Greater Cairo, although at least one heroic effort in the past has sought to quantify the instantaneous vehicular contribution of CO and NOx on an hourly basis for purposes of dispersion modeling (El Kotb & Borman, 1987). The greatest concentration reduction benefits to be realized in any CNG conversion program beyond simple dual fuel retrofit of diesel buses is in PM_{10} and sulfur oxides, with the potential for modest carbon monoxide reduction a minor secondary benefit. We conservatively assume that diesel vehicle-generated particulate (with resident carcinogens) represents 10 percent of the daytime particulate concentration in the breathing space of heavily-trafficked Cairo streets. Conversion to natural gas could presumably (in the absence of the confuting factors cited in Section 8) eliminate between 1 and 10 latent cancer fatalities out of every 10,000 per year among *longtime* Cairo inhabitants. The economic model, using Egypt / U.S. G.D.P. per capita proportioning for cost per tonne of pollution species emissions recently calculated in the U.S., estimated the value of benefits on the order of ten to twenty percent of the value of the fuel savings.

Recommendations

1. The CTA bus fleet should be converted to CNG operation. Any conversion program should be carefully designed and should include a comprehensive engineering phase and a thorough pilot phase to ensure successful operation. A comprehensive training program is needed as well. The following approach is recommended:

    a. New Buses: Each year the CTA purchases approximately 100 to 200 new buses depending on the available budget. These buses should be dedicated CNG vehicles. This may require the purchase of new dedicated CNG engines by a public sector company such as NASCO or a CTA garage shop or a private sector company to install in the new buses, and some slight re-engineering on the part of NASCO. Some relatively inexpensive CNG engines are available in the

American market, such that the incremental cost for a CNG bus should be small.

b. New engines: Each year the CTA purchases approximately 300 to 500 new engines for their bus fleet. These engines should be new dedicated CNG engines. Some slight re-engineering of the buses may be necessary to mount the new engines. These engines could be specially engineered for CNG and assembled in Egypt or a U.S. CNG engine.

c. Overhauls: Currently,after a new diesel engine has been in service five years it is overhauled every year. This overhaul costs L.E.20,000. Purchase of a new dedicated CNG engine instead of overhauling old diesels appears economical. If an overhaul can be saved for two years by using the new engines, L.E.40,000 can be saved. This would cover the majority of the costs for the new CNG engine.

d. Refueling stations: Using the approaches listed in a, b, and c above, the introduction of CNG can occur at a fast pace. Thus, the time before the fueling stations would be fully used would be short. Also, if the refueling stations can be configured and made accessible to other vehicles or fleets for daytime filling, the investment made in the stations can be reduced and more fleets, including bus, truck, and light duty vehicles, can be economically converted.

2. Public acceptance can be improved through a wide public information program. Development of a comprehensive safety program to include standards, regulations, testing, licensing, certification, inspection, and enforcement is essential.

3. The Ministry of Petroleum, Egypt Gas, the Egyptian CNG Committee, CTA, GCBC, EEAA, and USAID should consider a CNG bus fleet conversion and operation pilot program, preferably at one garage located close to a 30 bar natural gas line. If the gas in the high pressure line comes from the Abu Maadi and/or Abu Quir gas fields, then the cost of the compressors and fuel cost of compression will be less and the quality of the gas would meet the most stringent specifications for the natural gas for engines.
There is evidence that dual fuel conversion of existing diesel buses is not attractive from the point of fuel economy, field operation of the engines and emissions when compared to dedicated natural gas engines. It might be worthwhile therefore to test, select and install appropriate conversion kits to operate some diesel engines manufactured in Egypt as dedicated retrofit engines.

The Pilot Project should be planned and implemented as a regular revenue earning project so that engineering, economic and emission data can be generated. This data will be valuable to plan and implement natural gas use in Cairo's public service bus fleets.

4. This study was initiated in part because of the urgent need to improve air quality in Cairo. There are clear environmental and economic benefits if Cairo fleet vehicles use

natural gas fuel. Unfortunately, there are no **Emission Test Facilities** in Cairo to test the different engines and record the individual and collective contribution of vehicles to the overall air quality in Cairo. The Emission Test Facility can also be used to test and establish engine emission standards for vehicles in Cairo at this stage of its air quality development. Usually the established standards will have to be achieved over a period of time. Recommendations to the Legislature to pass emission standards based on data from the Test Facility would be better received than if emissions standards from other countries were to be recommended for Cairo.

The above recommendations are those that fall directly within the scope of work of this study. However, in the interest of furthering the CNG conversion efforts in Egypt in general, some additional strategic actions were identified. Based on the results of this study, the following actions are recommended as reasonable next steps:

- The Ministry of Petroleum has recognized that Egypt should develop a national strategy for conversion of portions of the transportation sector to CNG. This strategy may focus initially on Cairo, but may appropriately include eventual expansion of the CNG fueling station infrastructure beyond Cairo.

- The design of the initial fleet conversion program, as outlined above, should be begun.

- A detailed analysis of the long term natural gas pricing structure as applied to the transportation sector should be performed. The success of the CNG conversion program hinges on the long term stability, or at least predictability, of fuel prices.

- A major effort for the development of safety standards and an equipment certification program should begin early to ensure that unsafe equipment or procedures are not used. Failure or accidents early in the program due to improper equipment or procedures could seriously jeopardize acceptance of the program.

- An emissions testing facility should be established quickly to provide information for refinement of the program design, for program evaluation, for establishment of standards, and for emissions certification tests.

- The economic analysis model developed for this study should be documented and refined to maximize its value for analysis of other Egyptian fleet conversions and to support development of the national strategy and initial program design.

- A study should be performed to refine the environmental cost component of the economic model. The analysis was based on recently developed values for the cost of emissions of various pollutants in the U.S. These values were then decreased for application to Egypt based on the ratio of Egyptian GDP to U.S.

GDP. This simple proportioning of costs may underestimate benefits to Egypt.

- Several types of vehicles and fleets that could be potentially viable CNG conversion opportunities were not evaluated because adequate data were not available within the time limitations of this study. Study of additional fleets should continue. Examples of several candidates for early investigation are the Greater Cairo Bus Company public transit fleet, the bus fleets of the large industrial companies, and the microbus fleet.

- Liquified Natural Gas (LNG) vehicle technology is very similar to CNG technology. LNG offers the advantage of significantly reduced in-vehicle storage weight and space. An investigation of LNG use was not within the scope of this study, but may be worthwhile as part of a long term strategy.

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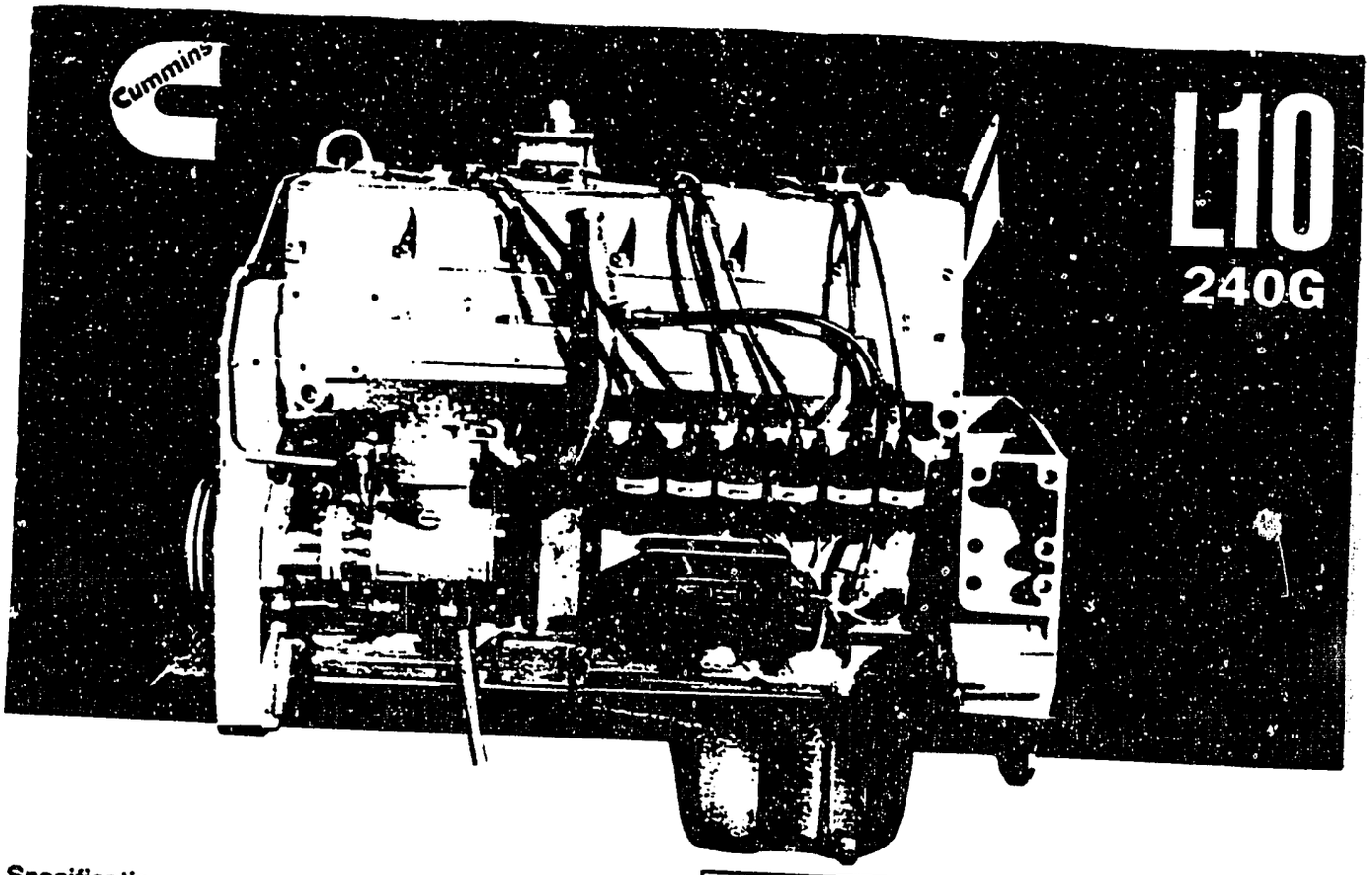
Appendix 1: Selected Descriptions of U.S.-made CNG Engines

Manufacturer:	Cummins Engine Company
Engine Model:	L10-240G Natural Gas
Warranty:	Base engine warranty 2 years after date in service; extended major components warranty.
Natural Gas Option Price:	Information not provided by manufacturer
Other information:	This engine is currently in limited production. See descriptive literature. CARB certified September 1992.
To order, contact:	Cummins Engine Company, Inc. P. O. Box 3005 Columbus, IN 47202 David O'Brien (812) 377-6445 Clark Ahrens (812) 377-3915

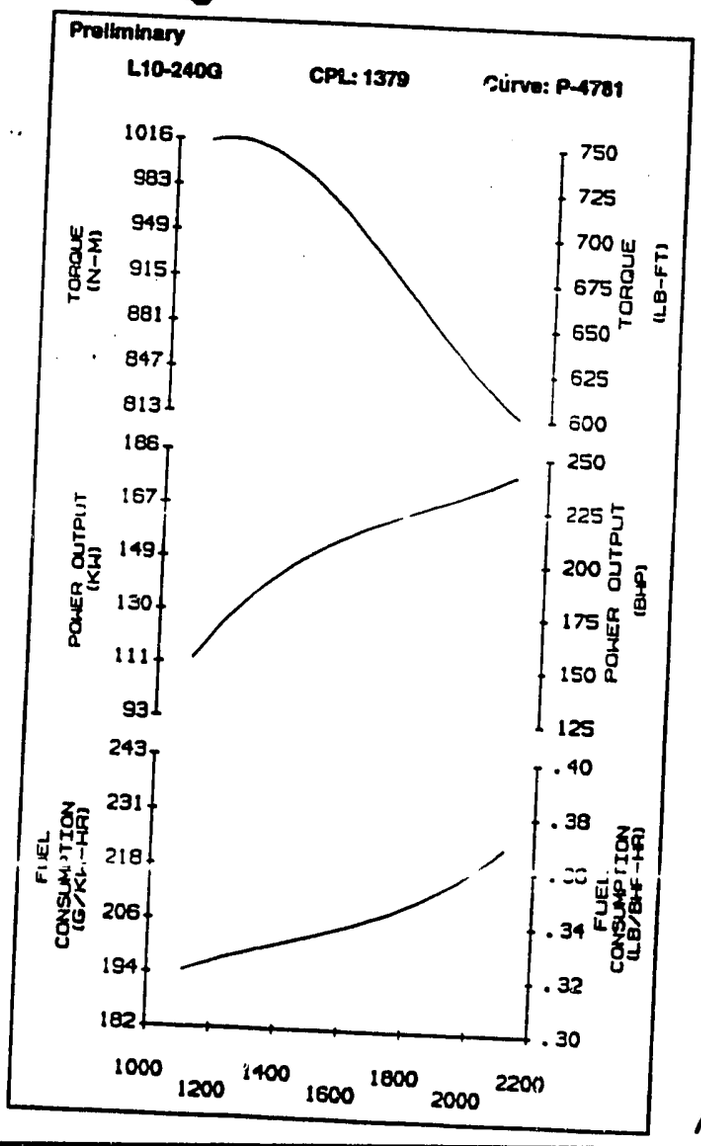


Specifications

Maximum Horsepower	240 bhp	(179 kW)
Peak Torque (1200 rpm)	750 lb.-ft.	(1 017 N•m)
Governed Speed	2100 rpm	(2100rpm)
Number of Cylinders	6	(6)
Bore and Stroke	4.921x5.354 in	(125x136mm)
Engine Displacement	611 cu.in.	(10 L)
Compression Ratio	10.5:1	(10.5:1)
Operating Cycles	4	(4)
*Oil System Capacity	10.3 U.S. gals	(39 L)
Coolant Capacity(Engine Only)	12 U.S. qts.	(11.3 L)
Net Weight with Std. Accessories, Dry	1955 lbs.	(887 kg)
Weight per Maximum Power	8.14lbs./hp	(4.9 kg/kW)

*With LF3000 Combo Filter

Note: "G" designates natural gas fueled - spark ignition.



PERFORMANCE:

Curves shown represent gross engine performance capabilities obtained and corrected in accordance with Cummins Standard. Standard Conditions are: 29.36 in.Hg (99.14kPa) barometric Pressure [500 ft. altitude, 77° F (25° C) Inlet Air Temperature, and Natural Gas having Octane Number 119, Gas Temperature 77° F (25° C) and Gas Wobbe Index 1215 (Specific Gravity 0.996, Lower Heating Value 950 BTU/cu.ft. measured by ASTM D-3588)]. The engine may be operated in a transient mode up to 8500 ft.(2780m) altitude and 100° F (38° C). However, when ambient and/or installed conditions vary from the Standard Conditions, performance characteristics can be expected to vary according to the guidelines in Cummins Standard.

The BSFC curve shown is at full load conditions. This is not a true indicator of fuel tank mileage due to the fact that the engine spends only a portion of time operating on the full load curve. A significant amount of time is spent at various part load conditions. Therefore, full load BSFC curves should not be used as an indicator of fuel tank mileage.

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L10

240G

Design Features

Bearings: Exceptionally large steel-backed tri-metal bearings throughout engine provide long engine life.

Camshaft: Injector lobe profile change provides increased injection pressures for improved performance.

Compuchek: Provision for easy application of Compuchek.

Connecting Rods: Drop forged, I-beam construction for strength. Tapered piston pin end provides stronger piston pin bore for durability.

Crankshaft: Induction hardened for strength. Large 4.5 in. (114mm) main bearings for durability.

Cylinder Block: Cast iron block. Redesigned to accommodate a large sump oil pan. New front end arrangement.

Cylinder Head: One-piece cylinder head reduces engine length and provides a rigid head-to-block fit. Ports are oriented to provide free intake and exhaust flow.

Cylinder Liners: Stiffened cylinder liner to reduce bore distortion.

Exhaust Manifold: Pulse design reduces back pressure for better fuel economy and more efficient exhaust flow to the turbocharger for outstanding throttle response and driveability. The exhaust ports have been redesigned to improve volume and flow.

Filters: The LF3000 combo full flow/by-pass oil filter is standard on new L10 ratings.

Lube Oil Cooler: Unitized design provides full flow oil cooling for high effectiveness and light weight.

Lube Pump: Gear pump is larger to improve flow for greater lube capacity.

Piston: The piston is made of high strength aluminum. A nickel alloy iron insert cast into the aluminum alloy piston encompasses the top ring groove for extended piston and ring life.

Turbocharger: Holset (Cummins) WH2-D turbo improves engine performance and response.

Valves: Dual intake and exhaust each cylinder. Generous valve area for less restricted gas flow for improved combustion and fuel economy. Premium material on valves for improved durability.

Vibration Damper: Viscous damper located outside front cover.

Water Pump: Sealed and supported internally for noise reduction.

Cummins has always been a pioneer in product improvement, thus specifications may change without notice. Illustrations may include optional equipment.

Put yourself in command.

Cummins Engine Company, Inc.
Box 3005
Columbus, IN 47202-3005
U.S.A.

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Manufacturer:	Hercules Engine Company
Engine Models:	GTA 5.6 liter, 6 cylinder GTA 3.7 liter, 4 cylinder
Warranty:	Information not provided by manufacturer
Natural Gas Option Price:	Information not provided by manufacturer
Other Information:	GTA 5.6 is CARB certified; see descriptive literature. GTA 3.7 is expected to receive CARB certification by third quarter 1993. For more information on GTA 3.7, contact Hercules Engine Company.
To order, contact:	Kim Boyer, Director Alternative Fuel Engine Sales Hercules Engine Company 101 Eleventh Street, SE Canton, OH 44707 (216) 438-1361 Michael Ervin, Vice President U.S. Sales and Distribution (216) 454-5631

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ON-HIGHWAY VEHICLE APPLICATION

BEST AVAILABLE DOCUMENT

Model GTA5.6

6 Cylinder Dedicated Natural Gas Turbocharged and Aftercooled BASIC ENGINE

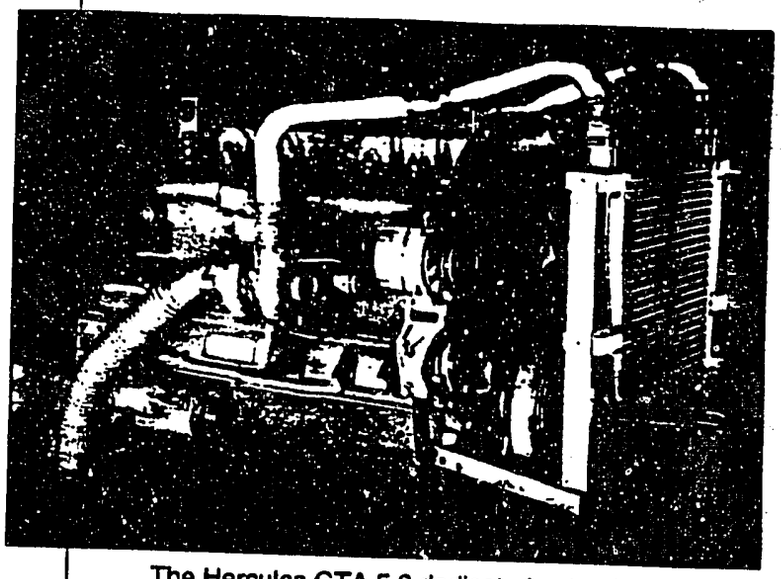
STANDARD EQUIPMENT

Cooling: belt driven, low mount water pump, oil cooler, 20" fan
Alternator mounting: for Delco 21SI series
Starter: Delco 10MT, 12 volt, mounted R/H below centerline
Flywheel and flywheel housing: SAE #3, for Allison AT545 transmission, includes flex plate
Fuel system: electronically controlled fuel management
Lubricating: gear driven oil pump, full flow oil filter, center sump oil pan
Turbocharger: with water cooled bearing and wastegate
Ignition system: 12 volt, capacitive discharge
Vibration damper: combination rubber-viscous
Accessory drives: for air compressor (belt driven) and steering pump (gear driven)

AVAILABLE EQUIPMENT

Air to air aftercooler: customer supplied, see technical data sheets for requirements
Additional accessory drives: on crankshaft or fan pulley for freon compressor or other accessories
Air compressor: various model air compressors (belt driven)
Alternator: 100 - 130 - 160 amp
High water pump: 15° to crankshaft centerline
Flywheels and flywheel housings: for various automatic and manual clutch transmissions
Front center engine support: bracket for Lord Sandwich mount (single point)
Oil pan: front or rear sump with oil level gauge
Coolant heater: mounted in cylinder block

Note: Additional equipment may be available. Please consult Hercules Engine Company for details.



The Hercules GTA 5.6 dedicated natural gas engine is engineered for high efficiency and low emissions. Special design characteristics give this engine an exceptionally long and trouble-free life.

VERSATILITY

- Variety of SAE standard flywheel and flywheel housing combinations for automatic and manual transmissions

LONG SERVICE LIFE

- High strength cast iron cylinder block can be rebored to .020 oversize
- Cast iron cylinder head incorporates crossflow design along with stellite alloy valve seats and stellite faced valves
- Forged alloy steel, I-beam connecting rods
- Forged steel crankshaft, surface hardened
- Aluminum alloy pistons with ni-resist top ring insert, 3 rings, 10:1 compression ratio and specially designed low turbulence lean burn combustion chamber
- Side mounted, gear driven, alloy cast iron camshaft
- 7 main tri-metal bearings

SERVICEABILITY

- Service components arranged for convenient access
- Nationwide distribution network provides field service support

HERCULES
ENGINE COMPANY

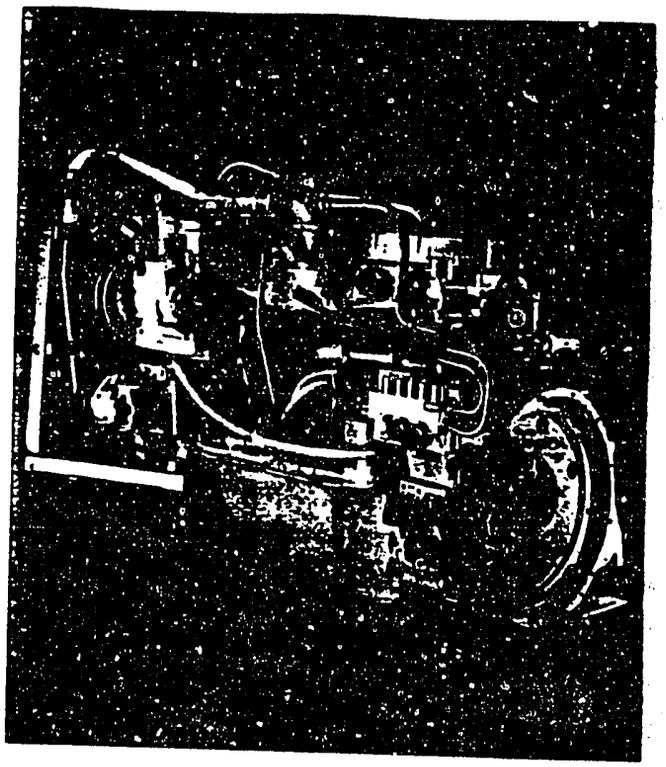
PUTTING POWER TO WORK

SINCE 1915

ON-HIGHWAY VEHICLE APPLICATION

Model GTA5.6

6 Cylinder Dedicated Natural Gas Turbocharged and Aftercooled BASIC ENGINE



SPECIFICATIONS

Displacement	339 cu. in.	5.6 liters
Bore and Stroke	4"x4-1/2"	101.6x114.3mm
Number of Cylinders	6	
Firing Order	1-5-3-6-2-4	
Compression Ratio	10:1	
Length	43.38"	1101.8mm
Height	33.60"	853.4mm
Width	28.90"	734.1mm

CAPACITIES

Water capacity incl. oil cooler	12 U.S. qts.	11.4 liters
Oil Pan – (includes 1 qt. for oil filter)	9 U.S. qts.	8.5 liters
Max. Tipping Angle (intermittent)	25°	

WEIGHT

Standard GTA 5.6 (dry)	1025 lbs.	464.9 kg.
GTA 5.6 less flywheel, flywheel housing and electronics	784 lbs.	356.4 kg.

INSTALLATION DRAWING

Standard GTA 5.6.....40-A-17743, Sheet 1
Optional Accessories.....40-A-17743, Sheet 2

NOTE:

. Engine performance per SAE standard J1349 conditions (29.31 In. Hg Barometer, 77°F. Air intake temperature 0.30 In. Hg Water vapor pressure) using 940 LHV natural gas fuel. Actual performance may vary with different ambient conditions. New engine power will be within -5% of curve shown.

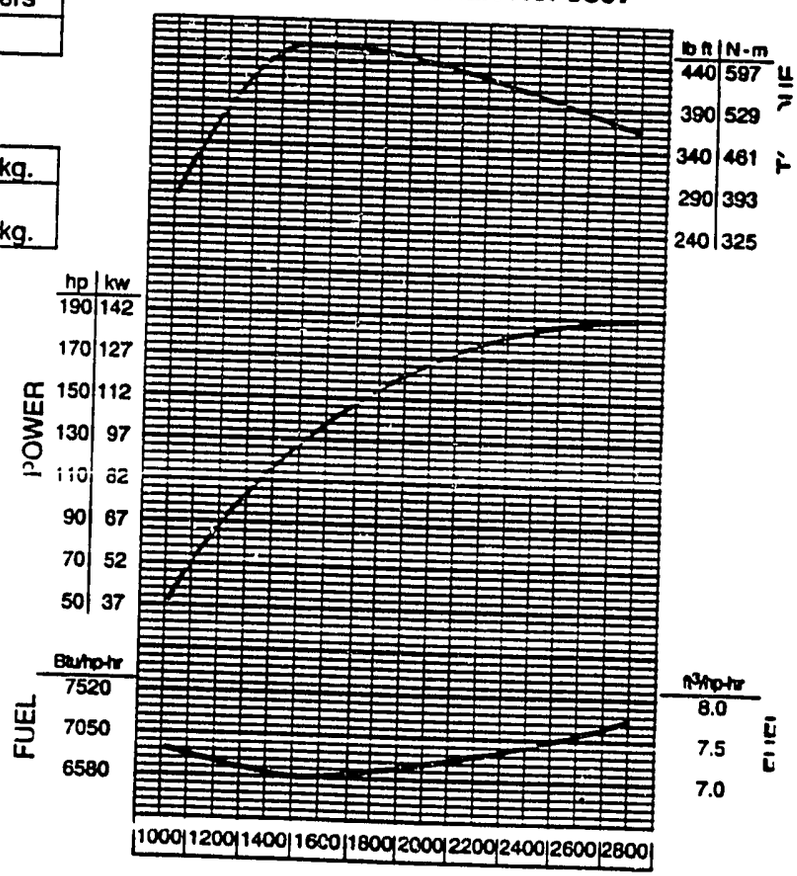
Curves shown represent performance of engine without alternator, power steering pump, air compressor and fan.

. Altitude correction:
- Deduct 2% per 1000 ft. (304.8m) above 500 ft. (152.4m)

. Temperature correction:
- Deduct 1% per 10°F (5.6°C) above 77°F (25.0°C)

NOTE: Hercules Engine Company reserves the right to change design or specifications without notice. Engine photograph depicts accessories that are not standard equipment.

GTA 5.6 Power Chart No. 3697



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Manufacturer: Navistar International Transportation Corporation

Engine Model: 7.3 liter (444 c.i.d.) turbocharged V8
Dedicated Natural Gas
210 horsepower at 2800 RPM

Projected Availability: January 1995

Other Information: Currently in prototype phase; intended production applications include school buses, pickup and delivery, and utility vehicles.

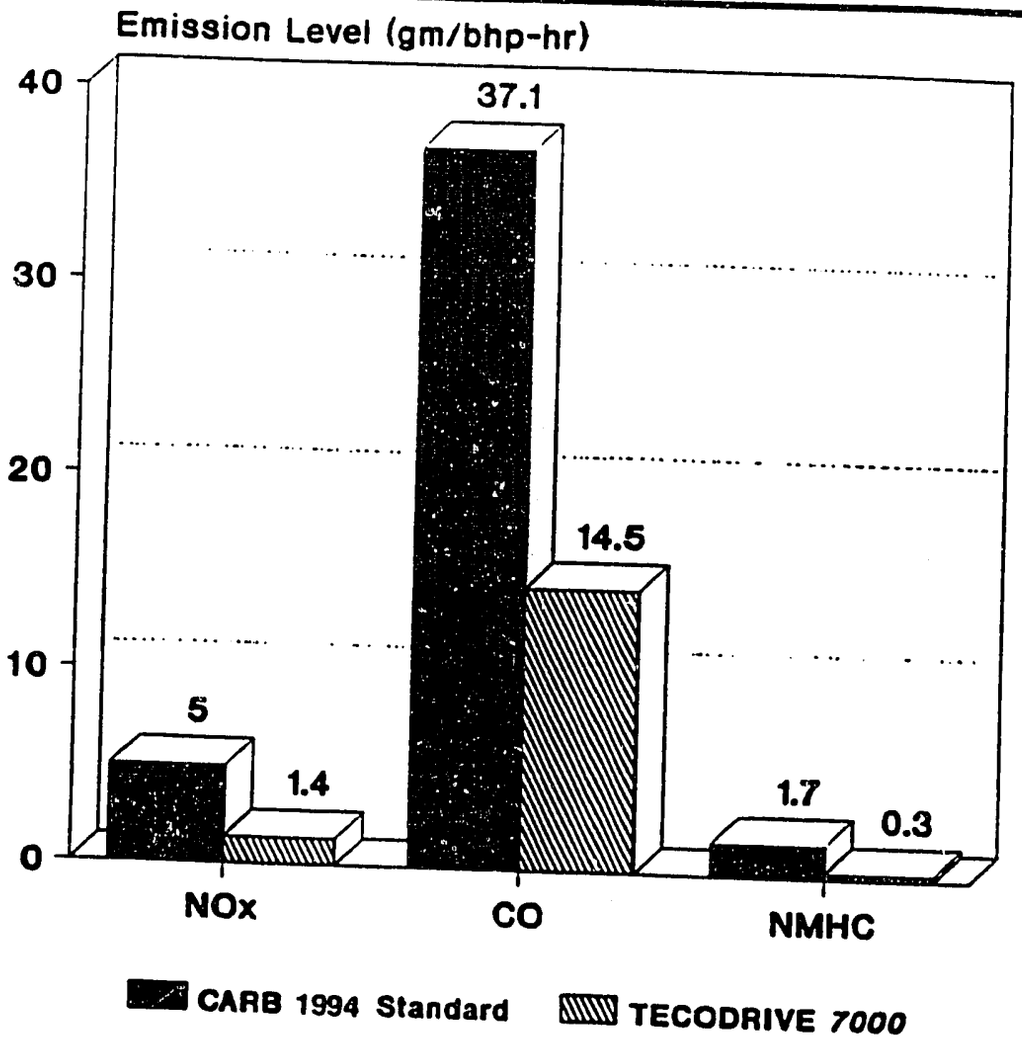
For more information, contact: Wayne Lucas
Marketing Representative
Navistar International
10400 West North Avenue
Melrose Park, IL 60160
(708) 865-4282

PROTOTYPE

Manufacturer:	Tecogen Inc.
Engine Model:	TECODRIVE 7000, 7.0 L dedicated natural gas, naturally aspirated, 195 hp @ 4000 rpm TECODRIVE 7000T, 7.0 L dedicated natural gas, turbocharged, after-cooled, 245 hp @ 3600 rpm
Warranty:	12 months or 12,000 miles; extended warranty available upon request
Natural Gas Option Price:	Available on request
Other Information:	TECODRIVE 7000 CARB certified to 1994 emission requirements. TECODRIVE 7000T CARB certification in progress. Variety of options available. Sales and service available through national distributor, United Environmental.
To order, contact:	Mark Corlee General Manager United Environmental Inc. P. O. Box 75389 Oklahoma City, OK 73147 Phone: (405) 942-1676 Fax: (405) 947-3406

TECODRIVE 7000

Emission Data



EPA Heavy Duty Gasoline Transient Test
(data includes deterioration factors)

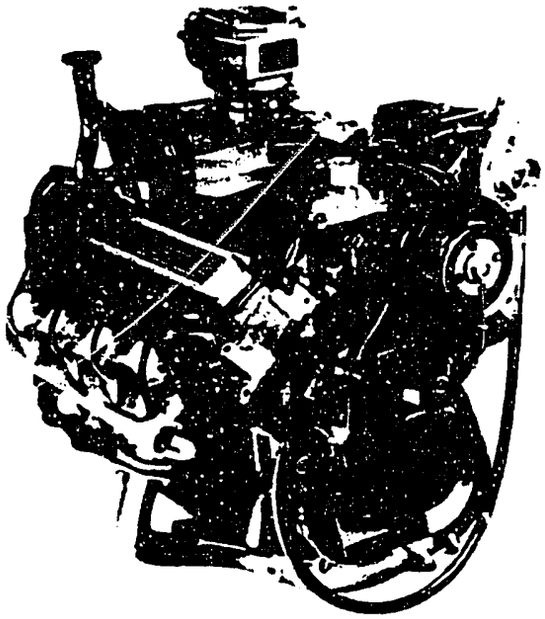
The bar chart compares results from emissions tests on the TecoDrive™ 7000 compressed natural gas engine (used for engine certification) with the emissions levels specified by the California Air Resources Board (CARB) for 1994. The TecoDrive emission measurements for oxides of nitrogen (NO_x), carbon monoxide (CO), and non-methane hydrocarbons (NMHC) were taken during a test conducted in accordance with the EPA's Federal Heavy-Duty Gasoline Transient Test Procedure. The emissions data gathered from the test was actually lower than that shown in the chart: NO_x = 1.1, CO = 9.3, and NMHC = 0.2. Deterioration factors, which account for wear and tear of the engine over its expected life, were used to adjust the test results, which still fall well within CARB emission standards.

TF3-293

2/93-1500

TECODRIVE 7000T

AUTOMOTIVE NATURAL GAS ENGINE



- *Dedicated Natural Gas*
- *Turbocharged*
- *Up to 245 HP; 425 ft.lb Torque*
- *Proven Reliability and Durability*
- *After-Cooled*
- *Superior Fuel Efficiency*
- *Standard Installation*
- *Application Flexibility*

The **TECODRIVE 7000T** is a turbocharged 7.0 liter displacement V-8 spark-ignition engine, developed by Tecogen Inc. for use with natural gas fuel. Tecogen Inc. has modified a General Motors engine and has added a turbocharger and an after-cooler to produce the additional power and torque required in certain applications. The turbocharger package has an integral waste gate and mechanical actuator for boost control, offering a compact design for the restricted under-hood space. The engine uses a customized electronic control module (ECM) which continuously optimizes the engine under varying loads and speeds. The engine is offered in a California Air Resources Board certified configuration. Durability and efficiency are proven by extensive laboratory and field service testing.

The clean-burning, low-emission **TECODRIVE 7000T** is a heavy-duty automotive engine with a forged steel crankshaft, cast-iron heads and block and optional cast-iron clutch housing, and is well suited for commercial vehicle operation. The **TECODRIVE 7000T** is available with a full complement of engine accessories.

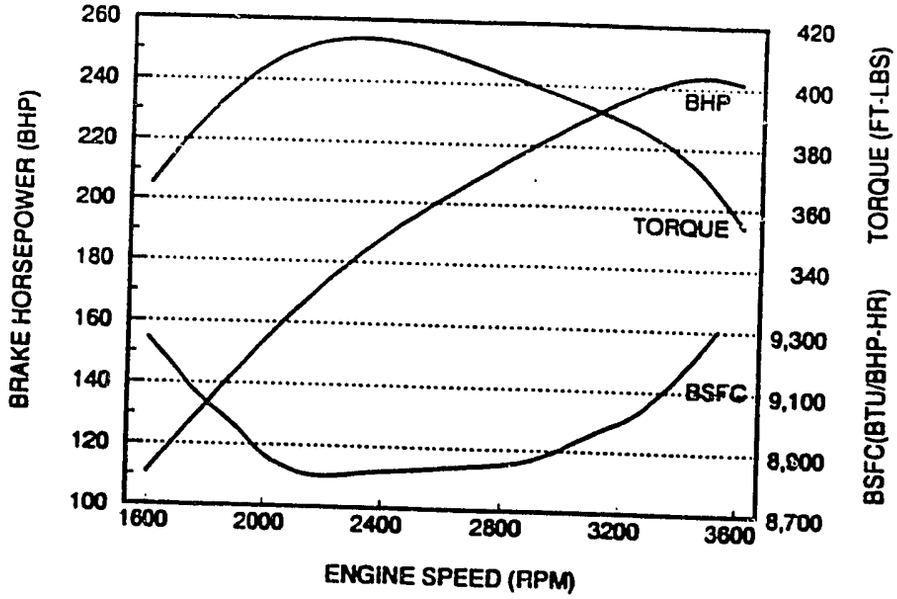
Performance of the **TECODRIVE** family of natural gas engines has been demonstrated in over ten million hours of reliable operation in Tecogen's stationary products and natural gas vehicles.

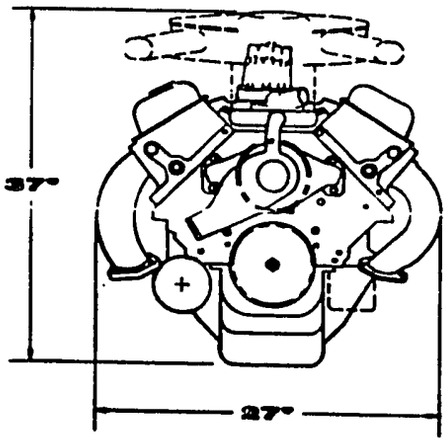
TECODRIVE DELIVERS INDUSTRIAL ENGINE DUTY WITH AUTOMOTIVE ENGINE AFFORDABILITY.

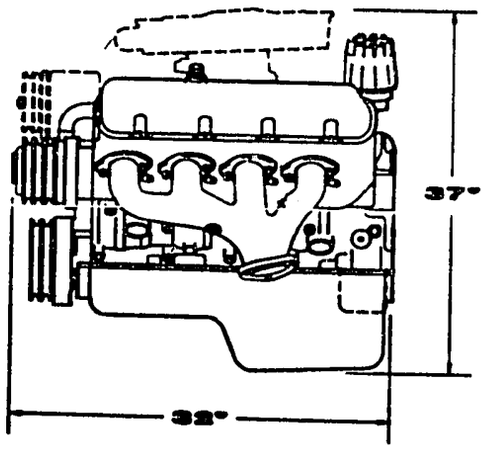
TECODRIVE 7000T Specifications

Cycle	4	**Lube Oil System Capacity**	8 quarts
Bore	4.25 in.	**Weight (Dry)**	895 lb
Stroke	3.76 in.	**Rated BHP**	245 @ 3600 rpm
Displacement	427 cu. in.	**Fuel**	Natural Gas 920 Btu/scf (LHV)
Aspiration	Turbocharged	**Torque**	425 ft lb @ 2200 rpm
After Cooler	Yes		

PERFORMANCE CURVES







INSTALLATION OF THE TURBOCHARGER AND AFTERCOOLER IS VEHICLE SPECIFIC

TECODRIVE 7000T net output at W.O.T. corrected to SAE 1349.
All specifications and materials subject to change without notice. All specifications and ratings are ±5%.

TECODRIVE
Crusader Engines
7100 E. 15 Mile Road
Sterling Heights, MI 48312

Tel (313) 264-1200
FAX (313) 264-2344
Built by Crusader Engines, a division of Teamgen Inc.

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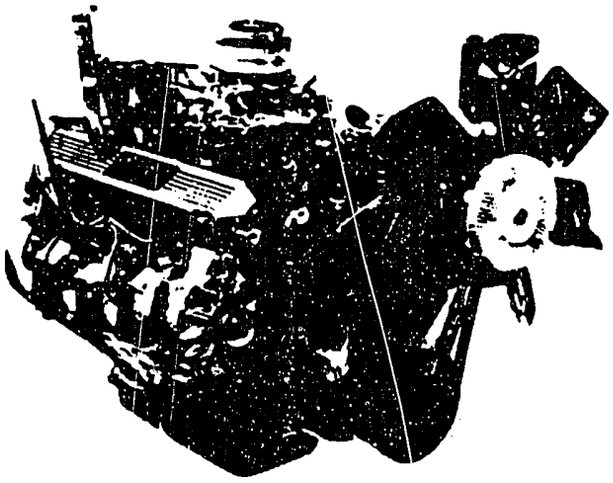
TECODRIVE 7000

AUTOMOTIVE NATURAL GAS ENGINE



- *Dedicated Natural Gas*
- *Lower Operating Costs*
- *Up to 195 HP*
- *Proven Reliability and Durability*
- *Extended Life*
- *Superior Fuel Efficiency*
- *Standard Installation*
- *Application Flexibility*

The **TECODRIVE 7000** is a 10.5-to-1 compression ratio 427-cubic-inch-(7.0 liter) displacement V-8 spark-ignition engine, developed for use with natural gas fuel. Tecogen has modified a General Motors gasoline-fueled engine to increase performance, durability, and efficiency for operation with natural gas fuel. Internal engine modifications include the use of special high-compression forged aluminum pistons, a long-life ring pack, and valve train modifications. Performance of the TECODRIVE family of natural gas engines has been demonstrated in millions of hours of reliable operation in Tecogen cogeneration and engine-driven chiller stationary power applications.

The **TECODRIVE 7000** engine is a heavy-duty automotive engine intended for use in trucks and buses. The cast-iron heads and block and the optional cast-iron clutch housing make this engine well suited for commercial vehicles. The engine can be ordered in a basic configuration that includes the gas mixer and a customized Electronics Control Module (ECM) or with a full complement of engine accessories.

The **TECODRIVE 7000** is a clean-burning, low-emission engine that is California Air Resources Board (CARB) certified to meet current emission standards for natural gas engines. TECODRIVE engines are used to power natural gas vehicles, packaged cogeneration systems, engine-driven water chillers and air conditioners, and irrigation pumps.

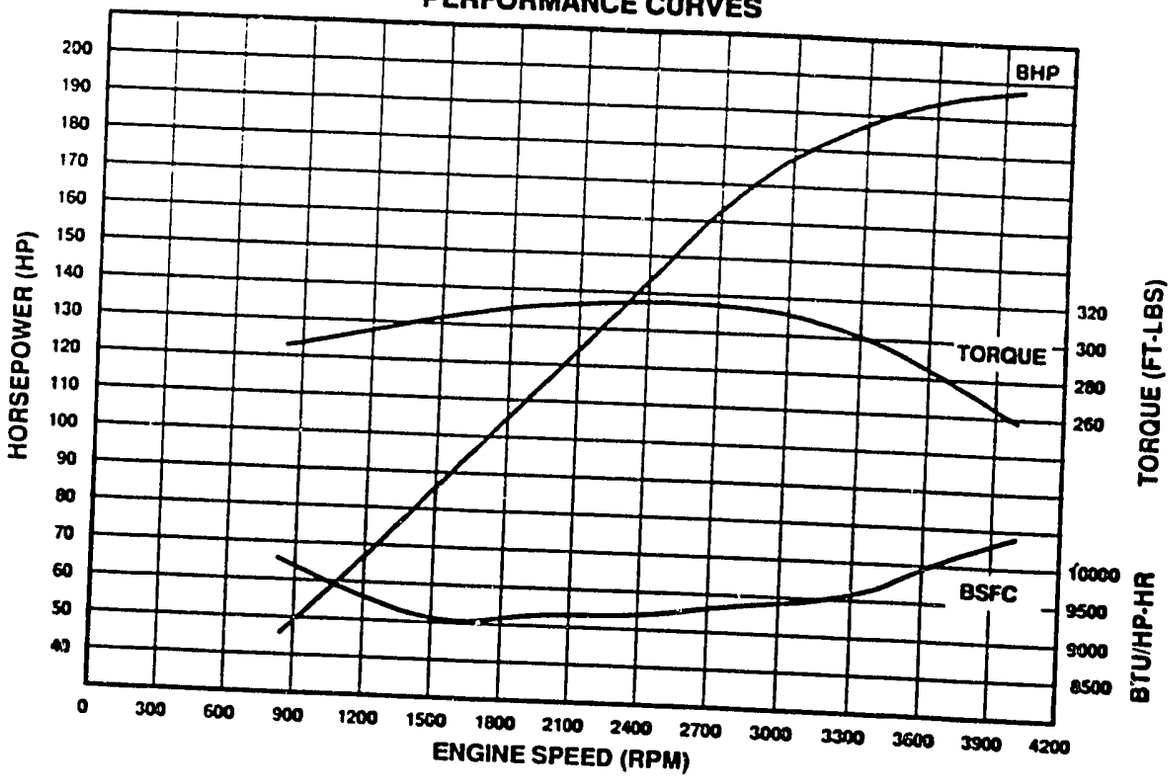
BEST AVAILABLE DOCUMENT

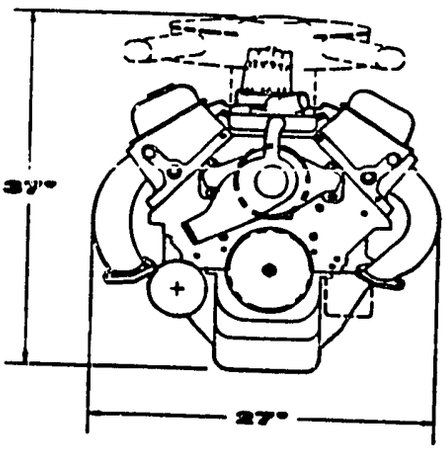
TECODRIVE DELIVERS INDUSTRIAL ENGINE DUTY WITH AUTOMOTIVE ENGINE AFFORDABILITY.

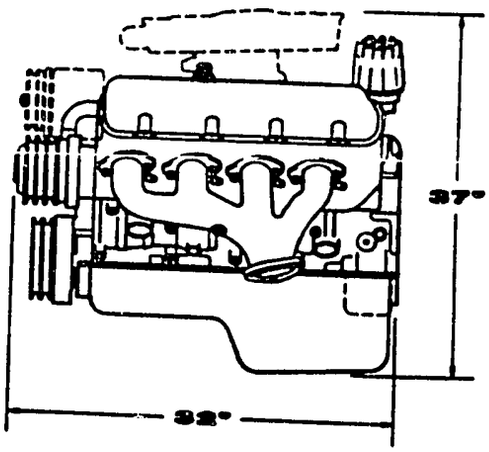
TECODRIVE 7000 Specifications

Cycle	4	**Lube Oil System Capacity**	8 quarts
Bore	4.25 in.	**Weight (Dry)**	865 lb
Stroke	3.76 in.	**Rated BHP**	195 @ 4000 rpm
Displacement	427 cu. in.	**Fuel**	Natural Gas 920 Btu/scf (LHV) or Propane
Compression Ratio	10.5 to 1		

PERFORMANCE CURVES







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TECODRIVE 7000 net output at W.O.T. corrected to SAE 1349.

All specifications and materials subject to change without notice.
All specifications and ratings are ±5%.

2/93 - 1000

Manufacturer:	Detroit Diesel Corporation
Engine Models:	6V92 Pilot Ignition Natural Gas (PING) 6V92 Direct Injection Natural Gas (DING)
Warranty:	Information not provided by manufacturer
Natural Gas Option Price:	Information not provided by manufacturer
Other Information:	PING is in full production for the 1993 model year; DING is in limited production. See descriptive literature on PING
To order, contact:	Nick Vermett Vice President, Engine Sales Detroit Diesel Corporation 13400 Outer Drive West Detroit, MI 48239 (313) 592-5292

DETROIT DIESEL

Natural Gas Engine

Detroit Diesel Pilot Ignition Natural Gas Engine

The Detroit Diesel 6V-92 Pilot Ignition Natural Gas engine will be offered for transit buses in the 1991 model year.

The Pilot Ignition Detroit Diesel Natural Gas engine operating principle is really very simple. Here's how it works:

The basic 6V-92 turbocharged and aftercooled engine is equipped with the Detroit Diesel Electronic Control (DDEC) system. The electronic fuel injector provides a pilot charge of diesel fuel into the combustion chamber. The fuel ignites in the chamber and in turn ignites a charge of natural gas. The charge of natural gas is timed into the cylinder via a high speed natural gas valve. The gas valve nozzle is located just above the normal intake ports in the liner.

The engine takes advantage of DDEC with the addition of a second electronic control module which performs the overall control function and also determines whether the engine is in diesel only or dual fuel mode.

At idle, the engine operates on 100% diesel fuel only. Above idle — depending upon the driving cycle, the engine switches to burn primarily natural gas, using a small amount of diesel fuel for continued combustion. This is known as the pilot ignition mode.

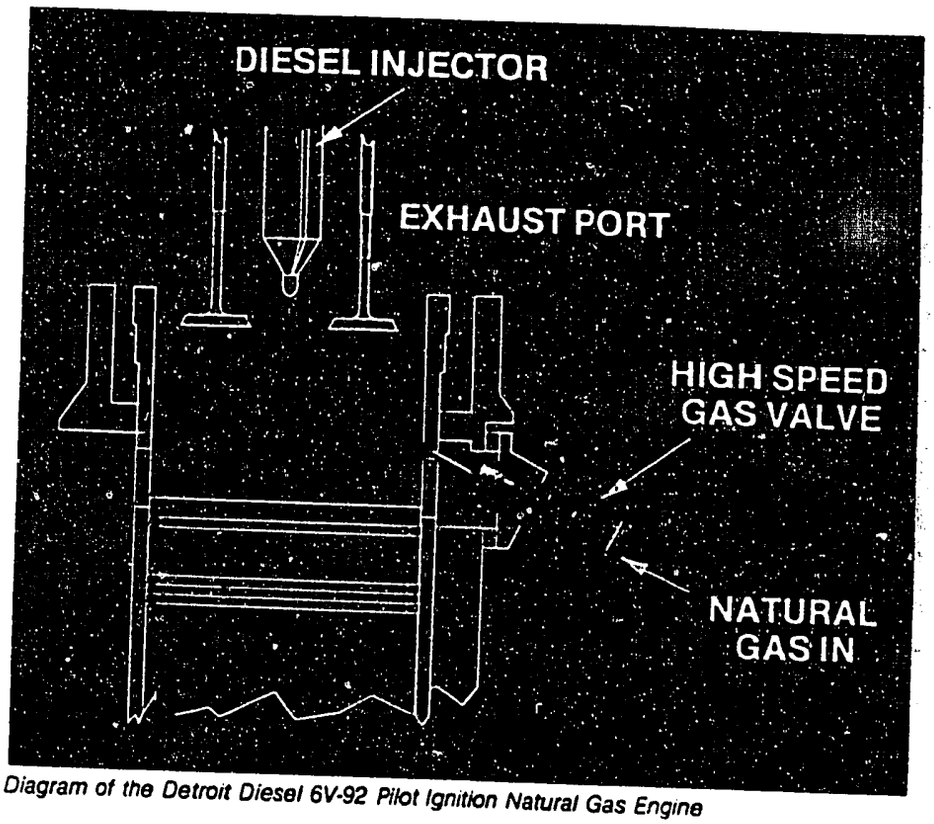

Diagram of the Detroit Diesel 6V-92 Pilot Ignition Natural Gas Engine

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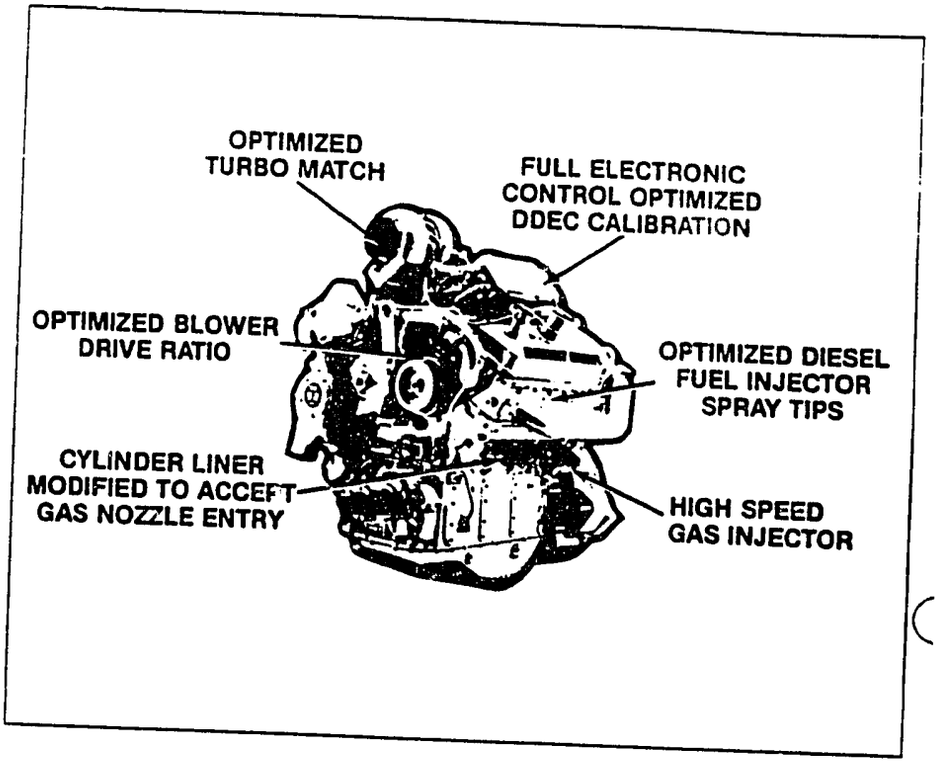
Pilot Ignition

Advantages of the Detroit Diesel Pilot Ignition Natural Gas Engine:

- Limp home capability — If the engine runs out of natural gas, the vehicle can still "limp" home on its secondary diesel fuel supply.
- The engine does not need any special materials or lubricating oils.
- The Pilot Ignition Natural Gas engine has lower particulate matter (BSP) emissions and lower peak and acceleration smoke than diesel engines.
- The Pilot Ignition Natural Gas engine, when equipped with a catalytic converter, is expected to meet the only currently legislated natural gas emission regulations, which have been set forth by the California Air Resources Board. Federal standards will probably be developed along the same lines as California.

The Pilot Ignition Natural Gas Engine Program participants are:

- DAI Technologies
- Detroit Diesel Corporation
- Gas Research Institute
- Ortech International
- Stewart & Stevenson Power, Inc.



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DETROIT DIESEL
CORPORATION

13400 Outer Drive, West / Detroit, Michigan 48239-4001
Telephone: 313-592-5000
Telex: 4320091 / TWX: 810-221-1649
FAX: 313-592-7288

Detroit Diesel® and the spinning arrows are registered trademarks of Detroit Diesel Corporation
SSA348 9105 As technical advancements continue, specifications will change. Litho in U.S.A.

Manufacturer: Caterpillar Inc.

Engine Model: G3306 Truck and Transit Bus Engine

Projected Availability: First quarter 1994

Other Information: G3306 specifications available upon request. Call number below and request form #LEHH 2133.

For more information, contact: Caterpillar Inc.
Engine Division
Bob Drake
P. O. Box 610, MOS 40
Mossville, IL 61552-0610

Phone: (309) 578-2557
Fax: (309) 578-7152

PROTOTYPE

Appendix 2: Economic Model input and Output Sheets for All Cases

Summary of Base Economic Cases With Selected Sensitivity Analyses

Case No.	CASE DESCRIPTORS	STATION and VEHICLE COSTS ($1000s)	FUEL SAVINGS BENEFITS ($1000S)	BENEFIT TO COST RATIO (excludes emissions values)	EXPORTS LESS IMPORTS ($1000S)	EMISSION DECLINE BENEFITS ($1000S) (rough estimate)	INTERNAL RATE OF RETURN ($1000S) (excludes emissions $)
	CAIRO TRANSIT BUS CASES						
	New Engine or New Dedicated Bus						
1A	Large Compressor	4040	9100	2.25	7220	2160	45%
1B	Large Storage	5010	9100	1.82	6670	2160	38%
	Retrofit Rebuiilt Engine Ded.						
2A	Large Compressor	4430	8900	2.01	6960	2160	38%
2B	Large Storage	5450	8900	1.63	6380	2160	32%
	Retrofit Oil Ignited Gas Engine						
3A	Large Compressor	4180	7660	1.83	5560	2020	34%
3B	Large Storage	5010	7660	1.53	5090	2020	29%
	Retrofit Old Engines Dual Fuel						
4A	Large Compressor	3470	5940	1.71	4620	940	30%
4B	Large Storage	4230	5940	1.40	4190	940	25%
	CAIRO BEVERAGE TRUCK CASE						
	New Engine or New Truck Ded.						
5A	Large Compressor	1430	1440	1.01	691	631	12%
5B	Large Storage	1610	1440	0.90	590	631	9%
	Retrofit Rebuilt Engine Ded.						
6A	Large Compressor	1700	1420	0.84	500	631	7%
6B	Large Storage	1880	1420	0.76	396	631	6%
	Retrofit Old Engines Dual Fuel						
7A	Large Compressor	1380	951	0.69	268	154	3%
7B	Large Storage	1513	951	0.63	191	154	1%
	AUTO/TRUCK GASOLINE TO CNG						
	New Dedicated						
8A	Large Compressor	962	541	0.56	7	83	0%
8B	Large Storage	1020	541	0.53	-27	83	-2%
	Retrofit Old Engines						
9A	Large Compressor	718	432	0.60	97	34	0%
9B	Large Storage	765	432	0.56	71	34	-1%
	SELECTED SENSITIVITY CASES						
5A1	Off-Peak Electricity @ 2¢/kWh	1400	1440	1.03	698	631	12%
5A2	Connection Distance 500 Meters	1290	1440	1.12	689	630	15%
5A3	50 Cairo Beverage Trucks to Existing Petrobell Station (Incremental Cost)	212	360	1.70	234	158	41%
8A1	Ded. Auto & Truck Using CTA Case A1 Station During Day (Incr. Cost)	1530	1440	0.94	322	221	4%
9A1	Bi-Fuel Auto & Truck Using CTA A1 Station During Day (Incr. Cost)	934	1150	1.23	530	91	8%
9a1*	Bi-Fuel Truck Only Using CTA A1 Station During Day (Incr. Cost)	1160	1640	1.41	864	116	18%

Notes: Costs and benefits are estimated in net present value terms using a 10% real interest rate. If internal rates of return are estimaated to be less than 10%, then the benefit to cost ratio should be less than 1.0 . The benefit to cost ratio presented here is the private rate - it does not include the social value of emissions reduction. To obtain an estimate of the benefit to cost ratio including the social benefits of emissions reduction, add the emissions decline benefits antd the fuel savings benefits together and divide by tht station and vehicle costs.

Sensitivity Analyses for Case A1

Case No.	CASE A1 MODIFICATION DESCRIPTION	STATION and VEHICLE COSTS ($1000s)	FUEL SAVINGS BENEFITS ($1000S)	BENEFIT TO COST RATIO (excludes emissions values)	EXPORTS LESS IMPORTS ($1000S)	EMISSION DECLINE BENEFITS ($1000S) (rough estimate)	INTERNAL RATE OF RETURN ($1000S) (excludes emissions $)
1A	New Engine or New Dedicated CNG Buses Served by Large Compressors	4040	9100	2.25	7220	2160	45%
1A1	33% Decline in Diesel Price	4040	5900	1.46	4010	2160	23%
1A2	56% Natural Gas Price Increase	4040	7010	1.74	7220	2160	30%
1A3	Double Vehicle Conversion Costs	5500	9100	1.66	6020	2160	29%
1A4	156% Increase in Storage Cost	4200	9100	2.17	7100	2160	43%
1A5	79% Increase in Compressor Cost	4550	9100	2.00	6790	2160	45%
1A6	25% Decrease in Daily Kilometers	3520	6830	1.94	5080	1620	36%
1A7	Double Import Taxes (40%)	4520	9100	2.01	7220	2160	NE
1A8	No Import Taxes	3560	9100	2.56	7220	2160	NE
1A9	33% Devaluation of Egyptian Pound	5000	13900	2.78	11200	2160	90%
1A10	10 Year Time Horizon	3840	6860	1.79	7260	1640	43%
1A11	Triple Labor Cost	4350	9100	2.09	7220	2160	43%
1A12	Triple Slow Fill Fraction	3970	9100	2.29	7260	2160	47%
1A13	Half Fill Rate Dispenser	4100	9100	2.22	7180	2160	44%
1A14	Double Station (twice as many buses)	7770	18200	2.34	14500	4320	50%
1A15	Half Station Size	2180	4550	2.09	3570	1080	38%
1A16	No Slow Fill	4060	9100	2.24	7200	2160	45%
1A17	30% Better Bus Fuel Economy	3530	7070	2.00	5270	2160	38%
1A18	29% More Time for Fast Fill	3760	9100	2.42	7390	2160	52%

Notes: Costs and benefits are estimated in net present value terms using a 10% real interest rate. If internal rates of return are estimated to be less than 10%, then the benefit to cost ratio should be less than 1.0 . The benefit to cost ratio presented here is the private rate - it does not include the social value of emissions reduction. To obtain an estimate of the benefit to cost ratio including the social benefits of emissions reduction, add the emissions decline benefits antd the fuel savings benefits together and divide by tht station and vehicle costs. NE indicates that the model , as structured on Oct. 30, did not properly estimate this value.

COMPRESSED NATURAL GAS	Typical CTA Bus Garage - Case 1A (Large Compressor)	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewBegin	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			0
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

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COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 1A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($322,57[illegible])
Compressor	($648,718)	Power	($330,00[illegible])
Storage Tanks	($65,188)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($213,500)		
Installation	($593,054)		
Subtotal	($1,590,783)		($654,850)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroOtNC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$2,163,479
Subtotal		$9,102,386	$2,163,479

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroOtN	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngin	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,590,783)
Station Operation Costs	($654,850)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($4,038,416)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$5,063,971
BENEFIT/COST RATIO	2.25
SAVINGS (COSTS) PER LITER	$0.042
SAVINGS (COSTS) / VEHICLE	$23,773
INTERNAL RATE OF RETURN	45%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,215,606
EMISSIONS CHANGE EFFECTS		$2,163,479
TOTAL BENEFITS LESS COSTS		$7,227,449

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3459	2510	2610	2668	2746	393	393	393	393	393	393	393
Fuel Savings	933	1866	2825	3758	4690	4690	4690	4690	4690	4690	4690	4690
Net Cash Outlay	2526	644	-215	-1090	-1945	-4298	-4298	-4298	-4298	-4298	-4298	-4298
Cash Outlay Sum	2526	3171	2956	1866	-79	-4377	-8674	-12972	-17270	-21568	-25866	-30164

COMPRESSED NATURAL GAS	Typical CTA Bus Garage - Case 1B (Large Storage)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($719,524)
Compressor	($308,201)	Power	($330,005)
Storage Tanks	($862,767)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($244,769)		
Installation	($579,914)		
Subtotal	($2,165,975)		($1,051,804)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPINO	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$2,163,479
Subtotal		$9,102,386	$2,163,479

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	1039
(in Standard Cubic Meters per hour)	1765
Storage Size (SCF)	1840559
(in Standard Cubic Meters)	52118

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($2,165,975)
Station Operation Costs	($1,051,804)
Station Gas Line Hookup Costs	($207,680)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($5,009,619)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$4,092,768
BENEFIT/COST RATIO	1.82
SAVINGS (COSTS) PER LITER	$0.034
SAVINGS (COSTS) / VEHICLE	$23,254
INTERNAL RATE OF RETURN	38%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($256,834)
Power Costs	30	($93,398)
Maintenance Costs	30	($203,639)
Station Storage Costs	100	($718,973)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($111,259)
Installation	50	($309,052)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$6,668,680
EMISSIONS CHANGE EFFECTS		$2,163,479
TOTAL BENEFITS LESS COSTS		$6,256,246

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPINO	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3708	2800	2946	3036	3152	586	586	586	586	586	586	586
Fuel Savings	933	1866	2825	3758	4690	4690	4690	4690	4690	4690	4690	4690
Net Cash Outlay	2775	934	121	-722	-1538	-4105	-4105	-4105	-4105	-4105	-4105	-4105
Cash Outlay Sum	2775	3709	3830	3108	1569	-2536	-6641	-10746	-14850	-18955	-23060	-27165

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 2A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>			% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline	Vehicle Name							Lead	CO	NMHC	NOx		Kit	Tanks	Labor Hrs			
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.1	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroOffNC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	220	1.8	1.5	98550	176	18	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	0	1.8	1.6	98550	0	0	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	Typical CTA Bus Garage - Case 2A (Large Compressor)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($339,774)
Compressor	($681,004)	Power	($347,606)
Storage Tanks	($68,460)	Refueling labor	($2,274)
Dispensers			
Fast	($54,284)		
Slow	($15,940)		
Miscellaneous	($223,552)		
Installation	($620,979)		
Subtotal	($1,664,319)		($689,654)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($792,608)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($152,095)	Maintenance	$0
Subtotal	($1,825,378)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroOINC	$0	$0
Vehicle Type 3	CTABusRetroDed	$8,904,255	$2,163,479
Vehicle Type 4	CTABusNewEngine	$0	$0
Subtotal		$8,904,255	$2,163,479

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2389
(in Standard Cubic Meters per hour)	4058
Storage Size (SCF)	138480
(in Standard Cubic Meters)	3921

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	TABusRetroOIN	0.0	0.0
Vehicle Type 3	CTABusRetroDed	12.1	13.2
Vehicle Type 4	TABusNewEngin	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,664,319)
Station Operation Costs	($689,654)
Station Gas Line Hookup Costs	($208,712)
Vehicle Completion Costs	($1,825,378)
Vehicle Operations Costs	($37,662)
TOTAL	($4,425,725)
BENEFITS	
Fuel Savings	$8,904,255
BENEFITS MINUS COSTS	$4,478,529
BENEFIT/COST RATIO	2.01
SAVINGS (COSTS) PER LITER	$0.035
SAVINGS (COSTS) / VEHICLE	$25,446
INTERNAL RATE OF RETURN	38%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($567,503)
Power Costs	30	($98,379)
Maintenance Costs	30	($96,162)
Station Storage Costs	100	($57,050)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($101,615)
Installation	50	($282,263)
Vehicle Conversion Kits	100	($660,507)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$6,957,040
EMISSIONS CHANGE EFFECTS		$2,163,479
TOTAL BENEFITS LESS COSTS		$6,642,008

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3724	2778	2884	2943	3024	409	409	409	409	409	409	409
Fuel Savings	912	1825	2763	3676	4588	4588	4588	4588	4588	4588	4588	4588
Net Cash Outlay	2812	953	120	-733	-1564	-4179	-4179	-4179	-4179	-4179	-4179	-4179
Cash Outlay Sums	2812	3764	3885	3151	1587	-2592	-6771	-10949	-15128	-19307	-23486	-27665

COMPRESSED NATURAL GAS	Typical CTA Bus Garage - Case 2B (Large Storage)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($757,898)
Compressor	($322,326)	Power	($347,606)
Storage Tanks	($908,577)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($256,490)		
Installation	($712,471)		
Subtotal	($2,270,187)		($1,107,778)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($792,608)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($152,095)	Maintenance	$0
Subtotal	($1,825,378)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroOINC	$0	$0
Vehicle Type 3	CTABusRetroDed	$8,904,255	$2,163,479
Vehicle Type 4	CTABusNewEngine	$0	$0
Subtotal		$8,904,255	$2,163,479

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	1090
(in Standard Cubic Meters per hour)	1852
Storage Size (SCF)	1938722
(in Standard Cubic Meters)	54898

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroOINC	0.0	0.0
Vehicle Type 3	CTABusRetroDed	12.1	13.2
Vehicle Type 4	CTABusNewEngine	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($2,270,187)
Station Operation Costs	($1,107,778)
Station Gas Line Hookup Costs	($207,719)
Vehicle Completion Costs	($1,825,378)
Vehicle Operations Costs	($37,662)
TOTAL	($5,448,726)
BENEFITS	
Fuel Savings	$8,904,255
BENEFITS MINUS COSTS	$3,455,529
BENEFIT/COST RATIO	1.63
SAVINGS (COSTS) PER LITER	$0.027
SAVINGS (COSTS) / VEHICLE	$19,634
INTERNAL RATE OF RETURN	32%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($268,605)
Power Costs	30	($98,379)
Maintenance Costs	30	($214,500)
Station Storage Costs	100	($757,147)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($116,586)
Installation	50	($323,851)
Vehicle Conversion Kits	100	($630,507)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$6,380,945
EMISSIONS CHANGE EFFECTS		$2,163,479
TOTAL BENEFITS LESS COSTS		$5,619,008

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3986	3083	3237	3330	3452	613	613	613	613	613	613	613
Fuel Savings	912	1825	2763	3676	4588	4588	4588	4588	4588	4588	4588	4588
Net Cash Outlay	3073	1258	474	-346	-1136	-3976	-3976	-3976	-3976	-3976	-3976	-3976
Cash Outlay Sum	3073	4332	4805	4459	3323	-653	-4628	-8604	-12579	-16555	-20531	-24506

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 3A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline																		
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroOtNG	220	1.8	1.6	98550	176	18	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	0	1.8	1.6	98550	0	0	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 3A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($320,015)
Compressor	($561,191)	Power	($282,291)
Storage Tanks	($56,317)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($186,247)		
Installation	($517,352)		
Subtotal	($1,394,430)		($604,581)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($1,100,844)	Cylinder Insp.	($37,662)
Tanks	($704,540)	Maintenance	$0
Labor	($127,759)		
Subtotal	($1,933,144)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroOINC	$7,659,237	$2,018,841
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$0	$0
Subtotal		$7,659,237	$2,018,841

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	1955
(in Standard Cubic Meters per hour)	3321
Storage Size (SCF)	112460
(in Standard Cubic Meters)	3184

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroOINC	9.8	11.3
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,391,430)
Station Operation Costs	($604,581)
Station Gas Line Hookup Costs	($208,381)
Vehicle Completion Costs	($1,933,144)
Vehicle Operations Costs	($37,662)
TOTAL	($4,175,198)
BENEFITS	
Fuel Savings	$7,659,237
BENEFITS MINUS COSTS	$3,484,039
BENEFIT/COST RATIO	1.83
SAVINGS (COSTS) PER LITER	$0.029
SAVINGS (COSTS) / VEHICLE	$19,796
INTERNAL RATE OF RETURN	34%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$8,127,807
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($467,659)
Power Costs	30	($79,894)
Maintenance Costs	30	($90,570)
Station Storage Costs	100	($46,931)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($84,658)
Installation	50	($235,160)
Vehicle Conversion Kits	100	($917,370)
Vehicle Tanks	100	($587,117)
NET EXPORT-IMPORT REVENUE		$5,559,845
EMISSIONS CHANGE EFFECTS		$2,018,841
TOTAL BENEFITS LESS COSTS		$5,502,881

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3545	2589	2677	2733	2804	357	357	357	357	357	357	357
Fuel Savings	785	1570	2377	3162	3947	3947	3947	3947	3947	3947	3947	3947
Net Cash Outlay	2760	1019	300	-429	-1143	-3590	-3590	-3590	-3590	-3590	-3590	-3590
Cash Outlay Sum	2760	3779	4080	3651	2508	-1082	-4672	-8262	-11851	-15441	-19031	-22621

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 3B (Large Storage) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($659,575)
Compressor	($269,907)	Power	($282,291)
Storage Tanks	($738,578)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($212,995)		
Installation	($591,653)		
Subtotal	($1,883,457)		($944,141)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicle			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($1,100,844)	Diesel	
Tanks	($704,540)	Cylinder Insp.	($37,662)
Labor	($127,759)	Maintenance	$0
Subtotal	($1,933,144)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroOINC	$7,659,237	$2,018,841
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$0	$0
Subtotal		$7,659,237	$2,018,841

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	901
(in Standard Cubic Meters per hour)	1530
Storage Size (SCF)	1574440
(in Standard Cubic Meters)	44583

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDua	0.0	0.0
Vehicle Type 2	CTABusRetroOIN	9.8	11.3
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngin	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,883,457)
Station Operation Costs	($944,141)
Station Gas Line Hookup Costs	($207,574)
Vehicle Completion Costs	($1,933,144)
Vehicle Operations Costs	($37,662)
TOTAL	($5,005,978)
BENEFITS	
Fuel Savings	$7,659,237
BENEFITS MINUS COSTS	$2,653,259
BENEFIT/COST RATIO	1.53
SAVINGS (COSTS) PER LITER	$0.022
SAVINGS (COSTS) / VEHICLE	$15,975
INTERNAL RATE OF RETURN	29%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$8,127,807
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($224,923)
Power Costs	30	($79,894)
Maintenance Costs	30	($186,672)
Station Storage Costs	100	($615,481)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($96,816)
Installation	50	($268,933)
Vehicle Conversion Kits	100	($917,370)
Vehicle Tanks	100	($587,117)
NET EXPORT-IMPORT REVENUE		$5,091,997
EMISSIONS CHANGE EFFECTS		$2,018,841
TOTAL BENEFITS LESS COSTS		$4,672,100

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3757	2837	2964	3048	3151	522	522	522	522	522	522	522
Fuel Savings	785	1570	2377	3162	3947	3947	3947	3947	3947	3947	3947	3947
Net Cash Outlay	2973	1267	587	-114	-795	-3425	-3425	-3425	-3425	-3425	-3425	-3425
Cash Outlay Sum	2973	4240	4827	4713	3917	493	-2932	-6357	-9781	-13206	-16631	-20056

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 4A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			**Diesel**					**SOx**				**PM**						
Vehicle Type 1	CTABusRetroDual	220	1.8	1.4	98530	176	18	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroOEM	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	0	1.8	1.6	98550	0	0	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 4A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($293,447)
Compressor	($518,200)	Power	($258,855)
Storage Tanks	($51,960)	Refueling labor	($1,935)
Dispensers			
Fast	($49,686)		
Slow	($15,940)		
Miscellaneous	($172,086)		
Installation	($478,015)		
Subtotal	($1,285,887)		($554,237)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($550,422)	Cylinder Insp.	($37,662)
Tanks	($704,540)	Maintenance	$0
Labor	($127,759)		
Subtotal	($1,382,722)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of: Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$5,942,781	$942,552
Vehicle Type 2	CTABusRetroOINC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$0	$0
Subtotal		$5,942,781	$942,552

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	1799
(in Standard Cubic Meters per hour)	3057
Storage Size (SCF)	103124
(in Standard Cubic Meters)	2920

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	9.0	10.6
Vehicle Type 2	CTABusRetroOINC	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,285,887)
Station Operation Costs	($554,237)
Station Gas Line Hookup Costs	($208,262)
Vehicle Completion Costs	($1,382,722)
Vehicle Operations Costs	($37,662)
TOTAL	($3,468,770)
BENEFITS	
Fuel Savings	$5,942,781
BENEFITS MINUS COSTS	$2,474,011
BENEFIT/COST RATIO	1.71
SAVINGS (COSTS) PER LITER	$0.022
SAVINGS (COSTS) / VEHICLE	$14,657
INTERNAL RATE OF RETURN	30%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$6,642,596
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($431,833)
Power Costs	30	($73,261)
Maintenance Costs	30	($83,051)
Station Storage Costs	100	($43,300)
Dispenser Costs	100	($54,688)
Miscellaneous Costs	50	($78,221)
Installation	50	($217,280)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($587,117)
NET EXPORT-IMPORT REVENUE		$4,615,160
EMISSIONS CHANGE EFFECTS		$942,552
TOTAL BENEFITS LESS COSTS		$3,416,563

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3078	2117	2198	2251	2285	332	332	332	332	332	332	332
Fuel Savings	609	1218	1844	2453	3062	3062	3062	3062	3062	3062	3062	3062
Net Cash Outlay	2469	900	354	-202	-777	-2730	-2730	-2730	-2730	-2730	-2730	-2730
Cash Outlay Sum	2469	3368	3722	3520	2743	13	-2717	-5447	-8177	-10906	-13636	-16366

COMPRESSED NATURAL GAS | Typical CTA Bus Garage - Case 4B (Large Storage) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($604,817)
Compressor	($251,099)	Power	($258,855)
Storage Tanks	($677,579)	Refueling labor	($1,935)
Dispensers			
Fast	($49,686)		
Slow	($15,940)		
Miscellaneous	($196,613)		
Installation	($546,148)		
Subtotal	($1,737,066)		($865,607)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($704,540)	Cylinder Insp.	($37,662)
Labor	($127,759)	Maintenance	$0
Subtotal	($1,382,722)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$5,942,781	$942,552
Vehicle Type 2	CTABusRetroOINC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$0	$0
Subtotal		$5,942,781	$942,552

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	832
(in Standard Cubic Meters per hour)	1414
Storage Size (SCF)	1443729
(in Standard Cubic Meters)	40881

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDua	9.0	10.6
Vehicle Type 2	TABusRetroOIN	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	TABusNewEngin	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,737,066)
Station Operation Costs	($865,607)
Station Gas Line Hookup Costs	($207,522)
Vehicle Completion Costs	($1,382,722)
Vehicle Operations Costs	($37,662)
TOTAL	($4,230,579)
BENEFITS	
Fuel Savings	$5,942,781
BENEFITS MINUS COSTS	$1,712,202
BENEFIT/COST RATIO	1.40
SAVINGS (COSTS) PER LITER	$0.015
SAVINGS (COSTS) / VEHICLE	$9,728
INTERNAL RATE OF RETURN	25%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$6,642,596
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($209,249)
Power Costs	30	($73,261)
Maintenance Costs	30	($171,175)
Station Storage Costs	100	($564,649)
Dispenser Costs	100	($54,688)
Miscellaneous Costs	50	($89,370)
Installation	50	($248,249)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($587,117)
NET EXPORT-IMPORT REVENUE		$4,186,153
EMISSIONS CHANGE EFFECTS		$942,552
TOTAL BENEFITS LESS COSTS		$2,654,754

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	3273	2345	2461	2540	2604	484	484	484	484	484	484	484
Fuel Savings	609	1218	1844	2453	3062	3062	3062	3062	3062	3062	3062	3062
Net Cash Outlay	2664	1127	617	87	-459	-2578	-2578	-2578	-2578	-2578	-2578	-2578
Cash Outlay Sum	2664	3791	4407	4494	4035	1457	-1122	-3700	-6279	-8857	-11435	-14014

COMPRESSED NATURAL GAS | Cairo Beverage Truck Case - Case 5A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.9	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			**Diesel**					**SOx**				**PM**						
Vehicle Type 1	TruckRetroDed	0	3.2	2.7	31200	0	0	0.8	-2.9	-2.7	1.5	0.20	2500	800	46	70	5	6
Vehicle Type 2	TruckRetroDed	0	3.2	2.8	31200	0	0	1.7	13.2	2.5	7.0	0.70	3600	800	46	100	5	6
Vehicle Type 3	TruckNewDed.	200	3.2	2.9	31200	160	16	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6
Vehicle Type 4	Place Holder	0	3.2	2.9	10000	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	312
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	Cairo Beverage Truck Case - Case 5A (Large Compressor)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($59,283)
Compressor	($134,792)	Power	($51,573)
Storage Tanks	($15,067)	Refueling labor	($1,135)
Dispensers			
Fast	($38,265)		
Slow	($3,445)		
Miscellaneous	($49,084)		
Installation	($136,343)		
Subtotal	($376,996)		($111,991)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($500,384)	Diesel	
Tanks	($160,123)	Cylinder Insp.	($34,239)
Labor	($39,242)	Maintenance	$0
Subtotal	($699,749)		($34,239)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$1,441,077	$630,559
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$1,441,077	$630,559

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	412
(in Standard Cubic Meters per hour)	699
Storage Size (SCF)	24066
(in Standard Cubic Meters)	681

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	2.3	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($376,996)
Station Operation Costs	($111,991)
Station Gas Line Hookup Costs	($207,199)
Vehicle Completion Costs	($699,749)
Vehicle Operations Costs	($34,239)
TOTAL	($1,430,174)
BENEFITS	
Fuel Savings	$1,441,077
BENEFITS MINUS COSTS	$10,903
BENEFIT/COST RATIO	1.01
SAVINGS (COSTS) PER LITER	$0.010
SAVINGS (COSTS) / VEHICLE	$68
INTERNAL RATE OF RETURN	12%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$1,516,237
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($112,326)
Power Costs	30	($14,596)
Maintenance Costs	30	($16,778)
Station Storage Costs	100	($12,556)
Dispenser Costs	100	($34,759)
Miscellaneous Costs	50	($22,311)
Installation	50	($61,974)
Vehicle Conversion Kits	100	($416,987)
Vehicle Tanks	100	($133,436)
NET EXPORT-IMPORT REVENUE		$690,514
EMISSIONS CHANGE EFFECTS		$630,559
TOTAL BENEFITS LESS COSTS		$641,462

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1760	723	775	761	780	95	95	95	95	95	95	95
Fuel Savings	149	297	446	594	743	743	743	743	743	743	743	743
Net Cash Outlay	1611	426	329	167	38	-648	-648	-648	-648	-648	-648	-648
Cash Outlay Sum	1611	2038	2367	2534	2572	1924	1276	629	-19	-667	-1314	-1962

COMPRESSED NATURAL GAS | Cairo Beverage Truck Case - Case 5B (Large Storage) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($131,951)
Compressor	($72,454)	Power	($51,573)
Storage Tanks	($161,077)	Refueling labor	($1,135)
Dispensers			
Fast	($38,265)		
Slow	($3,445)		
Miscellaneous	($54,808)		
Installation	($152,245)		
Subtotal	($482,294)		($184,661)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($500,384)	Cylinder Insp.	($34,239)
Tanks	($160,123)	Maintenance	$0
Labor	($39,242)		
Subtotal	($699,749)		($34,239)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$1,441,077	$630,559
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$1,441,077	$630,559

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	186
(in Standard Cubic Meters per hour)	316
Storage Size (SCF)	336927
(in Standard Cubic Meters)	9541

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	2.3	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($482,294)
Station Operation Costs	($184,661)
Station Gas Line Hookup Costs	($207,027)
Vehicle Completion Costs	($699,749)
Vehicle Operations Costs	($34,239)
TOTAL	($1,607,970)
BENEFITS	
Fuel Savings	$1,441,077
BENEFITS MINUS COSTS	($166,893)
BENEFIT/COST RATIO	0.90
SAVINGS (COSTS) PER LITER	($0.01)
SAVINGS (COSTS) / VEHICLE	($1,043)
INTERNAL RATE OF RETURN	9%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$1,516,237
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($60,379)
Power Costs	30	($14,596)
Maintenance Costs	30	($37,345)
Station Storage Costs	100	($134,231)
Dispenser Costs	100	($34,759)
Miscellaneous Costs	50	($24,913)
Installation	50	($69,202)
Vehicle Conversion Kits	100	($416,987)
Vehicle Tanks	100	($133,436)
NET EXPORT-IMPORT REVENUE		$590,390
EMISSIONS CHANGE EFFECTS		$630,559
TOTAL BENEFITS LESS COSTS		$463,666

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1806	777	835	829	855	130	130	130	130	130	130	130
Fuel Savings	149	297	446	594	743	743	743	743	743	743	743	743
Net Cash Outlay	1657	480	390	235	112	-612	-612	-612	-612	-612	-612	-612
Cash Outlay Sum	1657	2137	2526	2761	2873	2261	1649	1036	424	-188	-801	-1413

COMPRESSED NATURAL GAS	Cairo Beverage Truck Case - Case 6A (Large Compressor)	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>			% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
								Lead	CO	NMHC	NOx		Kit	Tanks	LaborHrs			
Gasoline	Vehicle Name																	
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	TruckRetroDed	0	3.2	2.7	31200	0	0	0.8	-2.9	-2.7	1.5	0.20	2500	800	46	70	5	6
Vehicle Type 2	TruckRetroDed	200	3.2	2.8	31200	160	16	1.7	13.2	2.5	7.0	0.70	3600	800	46	100	5	6
Vehicle Type 3	TruckNewDed.	0	3.2	2.9	31200	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6
Vehicle Type 4	Place Holder	0	3.2	2.9	10000	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	312
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS | Cairo Beverage Truck Case - Case 6A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($61,393)
Compressor	($138,838)	Power	($53,408)
Storage Tanks	($15,467)	Refueling labor	($1,135)
Dispensers			
Fast	($38,265)		
Slow	($3,511)		
Miscellaneous	($50,353)		
Installation	($139,868)		
Subtotal	($386,302)		($115,936)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($720,553)	Cylinder Insp.	($34,239)
Tanks	($160,123)	Maintenance	$0
Labor	($72,601)		
Subtotal	($953,277)		($34,239)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	15-Year Net Present Value of Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$1,420,416	$630,559
Vehicle Type 3	TruckNewDed.	$0	$0
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$1,420,416	$630,559

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	426
(in Standard Cubic Meters per hour)	724
Storage Size (SCF)	24923
(in Standard Cubic Meters)	706

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	2.4	5.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($386,302)
Station Operation Costs	($115,936)
Station Gas Line Hookup Costs	($207,211)
Vehicle Completion Costs	($953,277)
Vehicle Operations Costs	($34,239)
TOTAL	($1,696,963)
BENEFITS	
Fuel Savings	$1,420,416
BENEFITS MINUS COSTS	($276,547)
BENEFIT/COST RATIO	0.84
SAVINGS (COSTS) PER LITER	($0.01)
SAVINGS (COSTS) / VEHICLE	($1,728)
INTERNAL RATE OF RETURN	7%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$1,516,237
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($115,698)
Power Costs	30	($15,116)
Maintenance Costs	30	($17,375)
Station Storage Costs	100	($12,889)
Dispenser Costs	100	($34,814)
Miscellaneous Costs	50	($22,888)
Installation	50	($63,577)
Vehicle Conversion Kits	100	($600,461)
Vehicle Tanks	100	($133,636)
NET EXPORT-IMPORT REVENUE		$499,985
EMISSIONS CHANGE EFFECTS		$630,559
TOTAL BENEFITS LESS COSTS		$354,012

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1944	908	960	947	966	97	97	97	97	97	97	97
Fuel Savings	146	293	439	586	732	732	732	732	732	732	732	732
Net Cash Outlay	1798	615	521	361	234	-635	-635	-635	-635	-635	-635	-635
Cash Outlay Sum	1798	2413	2934	3295	3529	2894	2259	1624	989	354	-281	-917

COMPRESSED NATURAL GAS	Cairo Beverage Truck Case - Case 6B (Large Storage)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($136,649)
Compressor	($74,282)	Power	($53,408)
Storage Tanks	($166,673)	Refueling labor	($1,135)
Dispensers			
Fast	($38,261)		
Slow	($3,511)		
Miscellaneous	($56,281)		
Installation	($156,335)		
Subtotal	($495,347)		($191,192)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0		
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($720,553)	Diesel	
Tanks	($160,123)	Cylinder Insp.	($34,239)
Labor	($72,601)	Maintenance	$0
Subtotal	($953,277)		($34,239)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$1,420,416	$630,559
Vehicle Type 3	TruckNewDed.	$0	$0
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$1,420,416	$630,559

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	192
(in Standard Cubic Meters per hour)	327
Storage Size (SCF)	348917
(in Standard Cubic Meters)	9880

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	2.4	5.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($495,347)
Station Operation Costs	($191,192)
Station Gas Line Hookup Costs	($207,032)
Vehicle Completion Costs	($953,277)
Vehicle Operations Costs	($34,239)
TOTAL	($1,881,086)
BENEFITS	
Fuel Savings	$1,420,416
BENEFITS MINUS COSTS	($460,670)
BENEFIT/COST RATIO	0.76
SAVINGS (COSTS) PER LITER	($0.02)
SAVINGS (COSTS) / VEHICLE	($2,879)
INTERNAL RATE OF RETURN	6%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$1,516,237
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($61,902)
Power Costs	30	($15,116)
Maintenance Costs	30	($38,674)
Station Storage Costs	100	($138,894)
Dispenser Costs	100	($34,814)
Miscellaneous Costs	50	($25,582)
Installation	50	($71,062)
Vehicle Conversion Kits	100	($600,461)
Vehicle Tanks	100	($133,436)
NET EXPORT-IMPORT REVENUE		$396,298
EMISSIONS CHANGE EFFECTS		$630,559
TOTAL BENEFITS LESS COSTS		$169,889

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1991	963	1023	1017	1043	133	133	133	133	133	133	133
Fuel Savings	146	293	439	586	732	732	732	732	732	732	732	732
Net Cash Outlay	1845	671	523	431	311	-599	-599	-599	-599	-599	-599	-599
Cash Outlay Sum	1845	2516	3099	3530	3842	3243	2645	2046	1447	849	250	-348

COMPRESSED NATURAL GAS | Cairo Beverage Truck Case - Case 7A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>			% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline	Vehicle Name							Lead	CO	NMHC	NOx		Kit	Tanks	LaborHrs			
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	TruckRetroDual	200	3.2	2.7	31200	160	16	0.8	-2.9	-2.7	1.5	0.20	2500	800	46	70	5	6
Vehicle Type 2	TruckRetroDed	0	3.2	2.8	31200	0	0	1.7	13.2	2.5	7.0	0.70	3600	800	46	100	5	6
Vehicle Type 3	TruckNewDed.	0	3.2	2.9	31200	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6
Vehicle Type 4	Place Holder	0	3.2	2.9	10000	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			0
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	312
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	Cairo Beverage Truck Case - Case 7A (Large Compressor)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($45,57[illegible])
Compressor	($108,492)	Power	($39,64[illegible])
Storage Tanks	($12,469)	Refueling labor	($1,07[illegible])
Dispensers			
Fast	($37,749)		
Slow	($3,017)		
Miscellaneous	($40,750)		
Installation	($113,194)		
Subtotal	($315,670)		($86,28[illegible])

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0		
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($500,384)	Diesel	
Tanks	($160,123)	Cylinder Insp.	($34,239)
Labor	($72,601)	Maintenance	$0
Subtotal	($733,108)		($34,239)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$950,686	$154,217
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$0	$0
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$950,686	$154,217

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	316
(in Standard Cubic Meters per hour)	537
Storage Size (SCF)	18499
(in Standard Cubic Meters)	524

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	1.8	4.5
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($315,670)
Station Operation Costs	($86,288)
Station Gas Line Hookup Costs	($207,127)
Vehicle Completion Costs	($733,108)
Vehicle Operations Costs	($34,239)
TOTAL	($1,376,431)
BENEFITS	
Fuel Savings	$950,686
BENEFITS MINUS COSTS	($425,745)
BENEFIT/COST RATIO	0.69
SAVINGS (COSTS) PER LITER	($0.02)
SAVINGS (COSTS) / VEHICLE	($2,661)
INTERNAL RATE OF RETURN	[illegible]%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$1,047,720
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($90,410)
Power Costs	30	($11,220)
Maintenance Costs	30	($12,897)
Station Storage Costs	100	($10,391)
Dispenser Costs	100	($33,971)
Miscellaneous Costs	50	($18,523)
Installation	50	($51,452)
Vehicle Conversion Kits	100	($416,987)
Vehicle Tanks	100	($133,436)
NET EXPORT-IMPORT REVENUE		$268,435
EMISSIONS CHANGE EFFECTS		$154,217
TOTAL BENEFITS LESS COSTS		($271,528)

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1727	689	705	754	738	82	82	82	82	82	82	82
Fuel Savings	98	196	294	392	490	490	490	490	490	490	490	490
Net Cash Outlay	1629	493	411	362	248	-407	-407	-407	-407	-407	-407	-407
Cash Outlay Sum	1629	2122	2533	2896	3144	2736	2329	1922	1514	1107	699	292

COMPRESSED NATURAL GAS	Cairo Beverage Truck Case - Case 7B (Large Storage)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($101,430)
Compressor	($60,574)	Power	($39,643)
Storage Tanks	($124,704)	Refueling labor	($1,076)
Dispensers			
Fast	($37,749)		
Slow	($3,017)		
Miscellaneous	($45,150)		
Installation	($125,417)		
Subtotal	($396,610)		($142,149)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($500,384)	Diesel	
Tanks	($160,123)	Cylinder Insp.	($34,239)
Labor	($72,601)	Maintenance	$0
Subtotal	($733,108)		($34,239)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	15-Year Net Present Value of Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$950,686	$154,217
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$0	$0
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$950,686	$154,217

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	143
(in Standard Cubic Meters per hour)	243
Storage Size (SCF)	258989
(in Standard Cubic Meters)	7334

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	1.8	4.5
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($396,610)
Station Operation Costs	($142,149)
Station Gas Line Hookup Costs	($206,994)
Vehicle Completion Costs	($733,108)
Vehicle Operations Costs	($34,239)
TOTAL	($1,513,099)
BENEFITS	
Fuel Savings	$950,686
BENEFITS MINUS COSTS	($562,413)
BENEFIT/COST RATIO	0.63
SAVINGS (COSTS) PER LITER	($0.83)
SAVINGS (COSTS) / VEHICLE	($3,515)
INTERNAL RATE OF RETURN	1%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$1,047,720
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($50,479)
Power Costs	30	($11,220)
Maintenance Costs	30	($28,707)
Station Storage Costs	100	($103,920)
Dispenser Costs	100	($33,971)
Miscellaneous Costs	50	($20,523)
Installation	50	($57,008)
Vehicle Conversion Kits	100	($416,987)
Vehicle Tanks	100	($133,436)
NET EXPORT-IMPORT REVENUE		$191,471
EMISSIONS CHANGE EFFECTS		$154,217
TOTAL BENEFITS LESS COSTS		($408,196)

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1763	730	752	806	795	110	110	110	110	110	110	110
Fuel Savings	98	196	294	392	490	490	490	490	490	490	490	490
Net Cash Outlay	1665	534	458	414	306	-380	-380	-380	-380	-380	-380	-380
Cash Outlay Sum	1665	2198	2656	3070	3376	2996	2615	2235	1855	1474	1094	714

COMPRESSED NATURAL GAS | Auto and Truck Service Station - Case 8A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	150	10.6	11.2	14960	120	12	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	150	7.8	8.2	27200	120	12	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	TruckRetroDual	0	3.2	2.7	31200	0	0	0.8	-2.9	-2.7	1.5	0.20	2500	800	46	70	5	6
Vehicle Type 2	TruckRetroDed	0	3.2	2.8	31200	0	0	1.7	13.2	2.5	7.0	0.70	3600	800	46	100	5	6
Vehicle Type 3	TruckNewDed.	0	3.2	2.9	31200	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6
Vehicle Type 4	Place Holder	0	3.2	2.9	10000	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	272
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS | Auto and Truck Service Station - Case 8A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($1,882)
Compressor	($59,370)	Power	($15,135)
Storage Tanks	($7,617)	Refueling labor	($1,149)
Dispensers			
Fast	($38,265)		
Slow	($2,216)		
Miscellaneous	($25,429)		
Installation	($70,637)		
Subtotal	($203,535)		($18,166)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	($75,058)	Gasoline	
Tanks	($360,276)	Cylinder Insp.	($38,518)
Labor	($59,785)	Maintenance	$0
Diesel Vehicles			
Conversion Kit	$0	Diesel	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Subtotal	($495,119)		($38,518)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	15-Year Net Present Value of Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$156,174	$28,548
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$384,694	$54,471
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$0	$0
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$540,867	$83,019

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	139
(in Standard Cubic Meters per hour)	235
Storage Size (SCF)	8102
(in Standard Cubic Meters)	229

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.3	3.3
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.7	3.6
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($203,535)
Station Operation Costs	($18,166)
Station Gas Line Hookup Costs	($206,990)
Vehicle Completion Costs	($495,119)
Vehicle Operations Costs	($38,518)
TOTAL	($962,328)
BENEFITS	
Fuel Savings	$540,867
BENEFITS MINUS COSTS	($421,461)
BENEFIT/COST RATIO	0.56
SAVINGS (COSTS) PER LITER	($0.06)
SAVINGS (COSTS) / VEHICLE	($1,756)
INTERNAL RATE OF RETURN	0%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$0
Gasoline Fuel Use Avoided		$507,484
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($49,475)
Power Costs	30	($4,284)
Maintenance Costs	30	($533)
Station Storage Costs	100	($6,347)
Dispenser Costs	100	($33,735)
Miscellaneous Costs	50	($11,559)
Installation	50	($32,108)
Vehicle Conversion Kits	100	($62,548)
Vehicle Tanks	100	($300,230)
NET EXPORT-IMPORT REVENUE		$6,665
EMISSIONS CHANGE EFFECTS		$83,019
TOTAL BENEFITS LESS COSTS		($338,442)

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1449	405	449	427	438	54	54	54	54	54	54	54
Fuel Savings	56	111	167	223	279	279	279	279	279	279	279	279
Net Cash Outlay	1393	294	282	204	159	-224	-224	-224	-224	-224	-224	-224
Cash Outlay Sum	1393	1687	1969	2173	2332	2108	1884	1659	1435	1210	986	762

COMPRESSED NATURAL GAS | Auto and Truck Service Station - Case 8B (Large Storage) | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($26,345)
Compressor	($38,386)	Power	($15,135)
Storage Tanks	($56,769)	Refueling labor	($1,149)
Dispensers			
Fast	($38,265)		
Slow	($2,216)		
Miscellaneous	($27,356)		
Installation	($75,990)		
Subtotal	($238,982)		($42,630)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	($75,058)	Cylinder Insp.	($38,518)
Tanks	($360,276)	Maintenance	$0
Labor	($59,785)		
Diesel Vehicles		Diesel	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Subtotal	($495,119)		($38,518)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$156,174	$28,548
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$384,694	$54,471
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$0	$0
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$540,867	$83,019

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	63
(in Standard Cubic Meters per hour)	106
Storage Size (SCF)	113422
(in Standard Cubic Meters)	3212

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.3	3.3
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.7	3.6
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($238,982)
Station Operation Costs	($42,630)
Station Gas Line Hookup Costs	($206,932)
Vehicle Completion Costs	($495,119)
Vehicle Operations Costs	($38,518)
TOTAL	($1,022,181)
BENEFITS	
Fuel Savings	$540,867
BENEFITS MINUS COSTS	($481,313)
BENEFIT/COST RATIO	0.53
SAVINGS (COSTS) PER LITER	($0.07)
SAVINGS (COSTS) / VEHICLE	($2,885)
INTERNAL RATE OF RETURN	-2%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$0
Gasoline Fuel Use Avoided		$507,484
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($31,988)
Power Costs	30	($4,284)
Maintenance Costs	30	($7,456)
Station Storage Costs	100	($47,307)
Dispenser Costs	100	($33,735)
Miscellaneous Costs	50	($12,435)
Installation	50	($34,541)
Vehicle Conversion Kits	100	($62,548)
Vehicle Tanks	100	($300,230)
NET EXPORT-IMPORT REVENUE		($27,040)
EMISSIONS CHANGE EFFECTS		$83,019
TOTAL BENEFITS LESS COSTS		($398,294)

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1465	423	469	450	463	66	66	66	66	66	66	66
Fuel Savings	56	111	167	223	279	279	279	279	279	279	279	279
Net Cash Outlay	1409	312	302	227	184	-213	-213	-213	-213	-213	-213	-213
Cash Outlay Sum	1409	1721	2023	2250	2434	2221	2009	1796	1584	1371	1159	946

COMPRESSED NATURAL GAS | Auto and Truck Service Station - Case 9A (Large Compressor) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	150	10.6	11.6	14960	120	12	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	150	7.8	8.4	27200	120	12	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			**Diesel**					**SOx**				**PM**						
Vehicle Type 1	TruckRetroDual	0	3.2	2.7	31200	0	0	0.8	-2.9	-2.7	1.5	0.20	2500	800	46	70	5	6
Vehicle Type 2	TruckRetroDed	0	3.2	2.8	31200	0	0	1.7	13.2	2.5	7.0	0.70	3600	800	46	100	5	6
Vehicle Type 3	TruckNewDed.	0	3.2	2.9	31200	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6
Vehicle Type 4	Place Holder	0	3.2	2.9	10000	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
STATION COSTS	Percent Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
VEHICLE COSTS	Percent Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	272
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	Auto and Truck Service Station - Case 9A (Large Compressor)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($1,468)
Compressor	($50,960)	Power	($11,809)
Storage Tanks	($6,786)	Refueling labor	($1,150)
Dispensers			
Fast	($38,265)		
Slow	($2,079)		
Miscellaneous	($22,791)		
Installation	($63,309)		
Subtotal	($184,191)		($14,427)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	($60,046)	Gasoline	
Tanks	($157,621)	Cylinder Insp.	($38,518)
Labor	($56,657)	Maintenance	$0
Diesel Vehicles			
Conversion Kit	$0	Diesel	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Subtotal	($274,324)		($38,518)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$124,756	$12,439
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$307,037	$21,758
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$0	$0
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$431,793	$34,197

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	108
(in Standard Cubic Meters per hour)	184
Storage Size (SCF)	6321
(in Standard Cubic Meters)	179

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.2	3.2
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.6	3.5
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($184,191)
Station Operation Costs	($14,427)
Station Gas Line Hookup Costs	($206,967)
Vehicle Completion Costs	($274,324)
Vehicle Operations Costs	($38,518)
TOTAL	($718,428)
BENEFITS	
Fuel Savings	$431,793
BENEFITS MINUS COSTS	($286,635)
BENEFIT/COST RATIO	0.60
SAVINGS (COSTS) PER LITER	($0.86)
SAVINGS (COSTS) / VEHICLE	($1,194)
INTERNAL RATE OF RETURN	0%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$0
Gasoline Fuel Use Avoided		$402,942
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($42,466)
Power Costs	30	($3,342)
Maintenance Costs	30	($416)
Station Storage Costs	100	($5,655)
Dispenser Costs	100	($33,621)
Miscellaneous Costs	50	($[illegible])
Installation	50	($28,777)
Vehicle Conversion Kits	100	($50,038)
Vehicle Tanks	100	($131,351)
NET EXPORT-IMPORT REVENUE		$96,917
EMISSIONS CHANGE EFFECTS		$34,197
TOTAL BENEFITS LESS COSTS		($252,438)

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1282	237	281	258	269	52	52	52	52	52	52	52
Fuel Savings	44	89	133	178	222	222	222	222	222	222	222	222
Net Cash Outlay	1237	148	147	80	46	-170	-170	-170	-170	-170	-170	-170
Cash Outlay Sum	1237	1386	1533	1613	1659	1489	1319	1149	979	809	639	469

COMPRESSED NATURAL GAS	Auto and Truck Service Station - Case 9B (Large Storage)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($20,555)
Compressor	($34,586)	Power	($11,80[illegible])
Storage Tanks	($45,136)	Refueling labor	($1,15[illegible])
Dispensers			
Fast	($38,365)		
Slow	($2,079)		
Miscellaneous	($24,295)		
Installation	($67,486)		
Subtotal	($211,848)		($33,[illegible])

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	($60,046)	Gasoline	
Tanks	($157,621)	Cylinder Insp.	($38,518)
Labor	($56,657)	Maintenance	$0
Diesel Vehicles			
Conversion Kit	$0	Diesel	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Subtotal	($274,324)		($38,518)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	15-Year Net Present Value of Emissions
Vehicle Type 1	Auto Bi-Fuel	$124,756	$12,439
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$307,037	$21,758
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$0	$0
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$431,793	$34,197

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	49
(in Standard Cubic Meters per hour)	83
Storage Size (SCF)	88496
(in Standard Cubic Meters)	2506

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($211,848)
Station Operation Costs	($33,515)
Station Gas Line Hookup Costs	($206,922)
Vehicle Completion Costs	($274,324)
Vehicle Operations Costs	($38,518)
TOTAL	($765,127)
BENEFITS	
Fuel Savings	$431,793
BENEFITS MINUS COSTS	($333,334)
BENEFIT/COST RATIO	0.56
SAVINGS (COSTS) PER LITER	($0.06)
SAVINGS (COSTS) / VEHICLE	($1,389)
INTERNAL RATE OF RETURN	-1%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$0
Gasoline Fuel Use Avoided		$402,942
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($28,822)
Power Costs	30	($3,342)
Maintenance Costs	30	($5,818)
Station Storage Costs	100	($37,613)
Dispenser Costs	100	($33,621)
Miscellaneous Costs	50	($11,043)
Installation	50	($30,675)
Vehicle Conversion Kits	100	($50,038)
Vehicle Tanks	100	($131,351)
NET EXPORT-IMPORT REVENUE		$70,619
EMISSIONS CHANGE EFFECTS		$34,197
TOTAL BENEFITS LESS COSTS		($299,137)

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Average Time/Vehicle to Fill: Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.2	3.2
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.6	3.5
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1294	251	296	276	288	62	62	62	62	62	62	62
Fuel Savings	44	89	133	178	222	222	222	222	222	222	222	222
Net Cash Outlay	1249	162	163	98	66	-161	-161	-161	-161	-161	-161	-161
Cash Outlay Sum	1249	1412	1574	1673	1739	1578	1417	1256	1096	935	774	613

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COMPRESSED NATURAL GAS	Cairo Beverage Truck Case 5A1 (Off-Peak Electricity)	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>			% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline	Vehicle Name							Lead	CO	NMHC	NOx		Kit	Tanks	LaborHrs			
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	TruckRetroDual	0	3.2	2.7	31200	0	0	0.8	-2.9	-2.7	1.5	0.20	2500	800	46	70	5	6
Vehicle Type 2	TruckRetroDed	0	3.2	2.8	31200	0	0	1.7	13.2	2.5	7.0	0.70	3600	800	46	100	5	6
Vehicle Type 3	TruckNewDed.	200	3.2	2.9	31200	160	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6
Vehicle Type 4	Place Holder	0	3.2	2.9	10000	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.02
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	312
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	Cairo Beverage Truck Case 5A1 (Off-Peak Electricity)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($59,593)
Compressor	($138,075)	Power	($20,625)
Storage Tanks	($15,691)	Refueling labor	($1,038)
Dispensers			
Fast	($38,265)		
Slow	$0		
Miscellaneous	($49,586)		
Installation	($137,738)		
Subtotal	($379,355)		($81,260)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($500,384)	Diesel	
Tanks	($160,123)	Cylinder Insp.	($34,239)
Labor	($39,242)	Maintenance	$0
Subtotal	($699,749)		($34,239)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$1,441,077	$630,559
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$1,441,077	$630,559

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	423
(in Standard Cubic Meters per hour)	719
Storage Size (SCF)	25403
(in Standard Cubic Meters)	719

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($379,355)
Station Operation Costs	($81,260)
Station Gas Line Hookup Costs	($207,209)
Vehicle Completion Costs	($699,749)
Vehicle Operations Costs	($34,239)
TOTAL	($1,401,812)
BENEFITS	
Fuel Savings	$1,441,077
BENEFITS MINUS COSTS	$39,265
BENEFIT/COST RATIO	1.03
SAVINGS (COSTS) PER LITER	$0.002
SAVINGS (COSTS) / VEHICLE	$245
INTERNAL RATE OF RETURN	12%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$1,516,237
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($115,063)
Power Costs	30	($5,838)
Maintenance Costs	30	($16,866)
Station Storage Costs	100	($13,076)
Dispenser Costs	100	($31,888)
Miscellaneous Costs	50	($22,539)
Installation	50	($62,608)
Vehicle Conversion Kits	100	($416,987)
Vehicle Tanks	100	($133,436)
NET EXPORT-IMPORT REVENUE		$697,937
EMISSIONS CHANGE EFFECTS		$630,559
TOTAL BENEFITS LESS COSTS		$669,824

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1755	723	771	755	770	80	80	80	80	80	80	80
Fuel Savings	149	297	445	594	743	743	743	743	743	743	743	743
Net Cash Outlay	1606	426	326	161	28	-663	-663	-663	-663	-663	-663	-663
Cash Outlay Sum	1606	2032	2357	2518	2546	1883	1220	558	-105	-767	-1430	-2093

COMPRESSED NATURAL GAS	Cairo Beverage Truck Case 5A2 (Close to Pipeline)	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>			% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline	Vehicle Name							Lead	CO	NMHC	NOx		Kit	Tanks	LaborHrs			
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.6	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	TruckRetroDual	0	3.2	2.7	31200	0	0	0.8	-2.9	-2.7	1.5	0.20	2500	800	46	70	5	6
Vehicle Type 2	TruckRetroDed	0	3.2	2.8	31200	0	0	1.7	13.2	2.5	7.0	0.70	3600	800	46	100	5	6
Vehicle Type 3	TruckNewDed.	200	3.2	2.9	31200	160	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6
Vehicle Type 4	Place Holder	0	3.2	2.9	10000	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed	
(Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.19
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	312
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	Cairo Beverage Truck Case 5A2 (Close to Pipeline)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($59,593)
Compressor	($138,075)	Power	($51,571)
Storage Tanks	($15,691)	Refueling labor	($1,031)
Dispensers			
Fast	($38,265)		
Slow	$0		
Miscellaneous	($49,586)		
Installation	($137,738)		
Subtotal	($379,355)		($112,204)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0		
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles		Diesel	
Conversion Kit	($500,584)		
Tanks	($160,123)	Cylinder Insp.	($34,239)
Labor	($39,242)	Maintenance	$0
Subtotal	($699,749)		($34,239)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	15-Year Net Present Value of Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$1,441,077	$630,559
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$1,441,077	$630,559

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	423
(in Standard Cubic Meters per hour)	719
Storage Size (SCF)	25403
(in Standard Cubic Meters)	719

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($379,355)
Station Operation Costs	($112,204)
Station Gas Line Hookup Costs	($69,070)
Vehicle Completion Costs	($699,749)
Vehicle Operations Costs	($34,239)
TOTAL	($1,294,616)
BENEFITS	
Fuel Savings	$1,441,077
BENEFITS MINUS COSTS	$146,461
BENEFIT/COST RATIO	1.11
SAVINGS (COSTS) PER LITER	$0.007
SAVINGS (COSTS) / VEHICLE	$915
INTERNAL RATE OF RETURN	15%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$1,516,237
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($115,063)
Power Costs	30	($14,596)
Maintenance Costs	30	($16,866)
Station Storage Costs	100	($13,076)
Dispenser Costs	100	($31,888)
Miscellaneous Costs	50	($22,539)
Installation	50	($62,608)
Vehicle Conversion Kits	100	($416,987)
Vehicle Tanks	100	($133,436)
NET EXPORT-IMPORT REVENUE		$689,179
EMISSIONS CHANGE EFFECTS		$630,559
TOTAL BENEFITS LESS COSTS		$777,020

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	1292	729	780	767	786	95	95	95	95	95	95	95
Fuel Savings	149	297	446	594	743	743	743	743	743	743	743	743
Net Cash Outlay	1144	432	335	173	43	-648	-648	-648	-648	-648	-648	-648
Cash Outlay Sum	1144	1575	1910	2082	2125	1478	830	183	-465	-1113	-1760	-2408

COMPRESSED NATURAL GAS | Cairo Beverage Case 5A3 (50 Trucks Use Petrobell Station) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	TruckRetroDed	0	3.2	2.7	31200	0	0	0.8	-2.9	-2.7	1.5	0.20	2500	800	46	70	5	6
Vehicle Type 2	TruckRetroDed	0	3.2	2.8	31200	0	0	1.7	13.2	2.5	7.0	0.70	3600	800	46	100	5	6
Vehicle Type 3	TruckNewDed.	50	3.2	2.9	31200	40	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6
Vehicle Type 4	Place Holder	0	3.2	2.9	10000	0	0	1.7	13.2	2.5	7.0	0.70	2500	800	6	100	5	6

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	312
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	Cairo Beverage Case 5A3 (50 Trucks Use Petrobell Station)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($14,898)
Compressor	$0	Power	($12,893)
Storage Tanks	$0	Refueling labor	($586)
Dispensers			
Fast	$0		
Slow	$0		
Miscellaneous	$0		
Installation	$0		
Subtotal	$0		($28,377)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($125,096)	Cylinder Insp.	($8,560)
Tanks	($40,031)	Maintenance	$0
Labor	($9,811)		
Subtotal	($174,937)		($8,560)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	TruckRetroDual	$0	$0
Vehicle Type 2	TruckRetroDed	$0	$0
Vehicle Type 3	TruckNewDed.	$360,269	$157,640
Vehicle Type 4	Place Holder	$0	$0
Subtotal		$360,269	$157,640

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	106
(in Standard Cubic Meters per hour)	180
Storage Size (SCF)	6351
(in Standard Cubic Meters)	180

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	TruckRetroDual	0.0	0.0
Vehicle Type 2	TruckRetroDed	0.0	0.0
Vehicle Type 3	TruckNewDed.	0.0	4.9
Vehicle Type 4	Place Holder	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	$0
Station Operation Costs	($28,377)
Station Gas Line Hookup Costs	$0
Vehicle Completion Costs	($174,937)
Vehicle Operations Costs	($8,560)
TOTAL	($211,874)
BENEFITS	
Fuel Savings	$360,269
BENEFITS MINUS COSTS	$148,395
BENEFIT/COST RATIO	1.70
SAVINGS (COSTS) PER LITER	$0.027
SAVINGS (COSTS) / VEHICLE	$3,710
INTERNAL RATE OF RETURN	41%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$379,059
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	$0
Power Costs	30	($3,649)
Maintenance Costs	30	($4,217)
Station Storage Costs	100	$0
Dispenser Costs	100	$0
Miscellaneous Costs	50	$0
Installation	50	$0
Vehicle Conversion Kits	100	($104,247)
Vehicle Tanks	100	($33,359)
NET EXPORT-IMPORT REVENUE		$233,588
EMISSIONS CHANGE EFFECTS		$157,640
TOTAL BENEFITS LESS COSTS		$306,035

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	115	120	125	129	134	24	24	24	24	24	24	24
Fuel Savings	37	74	111	149	186	186	186	186	186	186	186	186
Net Cash Outlay	78	46	13	-19	-52	-162	-162	-162	-162	-162	-162	-162
Cash Outlay Sum	78	124	137	118	66	-96	-257	-419	-581	-743	-905	-1066

COMPRESSED NATURAL GAS | Autos and Trucks Using Bus Garage Station - Case 8A1 | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	400	10.5	11.2	14960	320	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	400	7.8	8.2	27200	320	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroCNG	0	1.6	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	0	1.8	1.6	98550	0	0	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	150[illegible]
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	305
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	272
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS | Autos and Trucks Using Bus Garage Station - Case 8A1 | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($5,297)
Compressor	$0	Power	($40,361)
Storage Tanks	$0	Refueling labor	($2,875)
Dispensers			
Fast	($61,262)		
Slow	$0		
Miscellaneous	$0		
Installation	$0		
Subtotal	($61,262)		($48,533)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	($200,154)	Gasoline	
Tanks	($960,737)	Cylinder Insp.	($102,716)
Labor	($159,426)	Maintenance	$0
Diesel Vehicles			
Conversion Kit	$0	Diesel	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Subtotal	($1,320,316)		($102,716)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	15-Year Net Present Value of Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$416,464	$76,128
Vehicle Type 3	Truck Bi-[illegible]	$0	$0
Vehicle Type 4	New Truck Ded.	$1,025,850	$145,256
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroOENC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngin	$0	$0
Subtotal		$1,442,313	$221,384

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	380
(in Standard Cubic Meters per hour)	646
Storage Size (SCF)	22804
(in Standard Cubic Meters)	646

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	3.2
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	3.6
Diesel			
Vehicle Type 1	CTABusRetroDua	0.0	0.0
Vehicle Type 2	CTABusRetroOEN	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngin	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($61,262)
Station Operation Costs	($48,533)
Station Gas Line Hookup Costs	$0
Vehicle Completion Costs	($1,320,316)
Vehicle Operations Costs	($102,716)
TOTAL	($1,532,827)
BENEFITS	
Fuel Savings	$1,442,313
BENEFITS MINUS COSTS	($90,513)
BENEFIT/COST RATIO	0.94
SAVINGS (COSTS) PER LITER	$0.000
SAVINGS (COSTS) / VEHICLE	($141)
INTERNAL RATE OF RETURN	4%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$0
Gasoline Fuel Use Avoided		$1,353,290
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	$0
Power Costs	30	($11,423)
Maintenance Costs	30	($1,499)
Station Storage Costs	100	$0
Dispenser Costs	100	($51,052)
Miscellaneous Costs	50	$0
Installation	50	$0
Vehicle Conversion Kits	100	($166,795)
Vehicle Tanks	100	($800,614)
NET EXPORT-IMPORT REVENUE		$321,907
EMISSIONS CHANGE EFFECTS		$221,384
TOTAL BENEFITS LESS COSTS		$130,870

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	943	992	1040	1088	1136	333	333	333	333	333	333	333
Fuel Savings	149	297	446	595	743	743	743	743	743	743	743	743
Net Cash Outlay	795	694	594	494	393	-410	-410	-410	-410	-410	-410	-410
Cash Outlay Sum	795	1489	2083	2577	2970	2560	2150	1740	1329	919	509	99

COMPRESSED NATURAL GAS	Autos and Trucks Using Bus Garage Station - Case 9A1	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

								<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>					
Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	Lead	CO	NMHC	NOx		Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	400	10.6	11.6	14960	320	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	400	7.8	8.4	27200	320	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroOEM	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	0	1.8	1.6	98550	0	0	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed	
(Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	272
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS | Autos and Trucks Using Bus Garage Station - Case 9A1 | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($4,133)
Compressor	$0	Power	($31,492)
Storage Tanks	[illegible]	Refueling labor	($2,875)
Dispensers			
Fast	($61,262)		
Slow	$0		
Miscellaneous	$0		
Installation	$0		
SubTotal	($61,262)		($38,499)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	($160,123)	Gasoline	
Tanks	($420,322)	Cylinder Insp.	($102,716)
Labor	($151,086)	Maintenance	$0
Diesel Vehicles			
Conversion Kit	$0	Diesel	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Subtotal	($731,531)		($102,716)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$332,683	$33,171
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$818,764	$58,021
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroOINC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$0	$0
Subtotal		$1,151,447	$91,192

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	297
(in Standard Cubic Meters per hour)	504
Storage Size (SCF)	17793
(in Standard Cubic Meters)	504

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	3.2
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	3.5
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroOINC	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($61,262)
Station Operation Costs	($38,499)
Station Gas Line Hookup Costs	$0
Vehicle Completion Costs	($731,531)
Vehicle Operations Costs	($102,716)
TOTAL	($934,008)
BENEFITS	
Fuel Savings	$1,151,447
BENEFITS MINUS COSTS	$217,439
BENEFIT/COST RATIO	1.23
SAVINGS (COSTS) PER LITER	$0.014
SAVINGS (COSTS) / VEHICLE	$349
INTERNAL RATE OF RETURN	8%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$0
Gasoline Fuel Use Avoided		$1,074,512
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	$0
Power Costs	30	($8,913)
Maintenance Costs	30	($1,170)
Station Storage Costs	100	$0
Dispenser Costs	100	($51,052)
Miscellaneous Costs	50	$0
Installation	50	$0
Vehicle Conversion Kits	100	($133,436)
Vehicle Tanks	100	($350,269)
NET EXPORT-IMPORT REVENUE		$529,674
EMISSIONS CHANGE EFFECTS		$91,192
TOTAL BENEFITS LESS COSTS		$308,631

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	545	592	639	687	734	328	328	328	328	328	328	328
Fuel Savings	119	237	356	475	593	593	593	593	593	593	593	593
Net Cash Outlay	426	355	283	212	141	-265	-265	-265	-265	-265	-265	-265
Cash Outlay Sum	426	781	1064	1276	1417	1152	886	621	356	91	-174	-439

COMPRESSED NATURAL GAS | Only Trucks Using Bus Garage Station - Case 9A1* | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($5,906)
Compressor	$0	Power	($45,003)
Storage Tanks	$0	Refueling labor	($2,875)
Dispensers			
Fast	($61,262)		
Slow	$0		
Miscellaneous	$0		
Installation	$0		
Subtotal	($61,262)		($53,784)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	($160,123)	Gasoline	
Tanks	($560,430)	Cylinder Insp.	($136,954)
Labor	($190,328)	Maintenance	$0
Diesel Vehicles			
Conversion Kit	$0	Diesel	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Subtotal	($910,881)		($136,954)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$1,637,528	$116,041
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroOfNC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngin	$0	$0
Subtotal		$1,637,528	$116,041

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	424
(in Standard Cubic Meters per hour)	720
Storage Size (SCF)	25427
(in Standard Cubic Meters)	720

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	3.5
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDua	0.0	0.0
Vehicle Type 2	CTABusRetroOfN	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngin	0.0	0.0

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($61,262)
Station Operation Costs	($53,784)
Station Gas Line Hookup Costs	$0
Vehicle Completion Costs	($910,881)
Vehicle Operations Costs	($136,954)
TOTAL	($1,162,881)
BENEFITS	
Fuel Savings	$1,637,528
BENEFITS MINUS COSTS	$474,647
BENEFIT/COST RATIO	1.41
SAVINGS (COSTS) PER LITER	$0.022
SAVINGS (COSTS) / VEHICLE	$742
INTERNAL RATE OF RETURN	18%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$0
Gasoline Fuel Use Avoided		$1,529,363
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	$0
Power Costs	30	($12,737)
Maintenance Costs	30	($1,672)
Station Storage Costs	100	$0
Dispenser Costs	100	($51,052)
Miscellaneous Costs	50	$0
Installation	50	$0
Vehicle Conversion Kits	100	($133,436)
Vehicle Tanks	100	($467,025)
NET EXPORT-IMPORT REVENUE		$863,942
EMISSIONS CHANGE EFFECTS		$116,041
TOTAL BENEFITS LESS COSTS		$590,688

BEST AVAILABLE DOCUMENT

ESTIMATE OF UNDISCOUNTED NET CASH OUTLAY IN EGYPTIAN POUNDS (1000s)

Year >>>>	1	2	3	4	5	6	7	8	9	10	11	12
Expenditures	645	702	758	815	872	376	376	376	376	376	376	376
Fuel Savings	169	338	506	675	844	844	844	844	844	844	844	844
Net Cash Outlay	476	364	252	140	28	-468	-468	-468	-468	-468	-468	-468
Cash Outlay Sum	476	840	1092	1232	1261	793	325	-143	-610	-1078	-1546	-2014

COMPRESSED NATURAL GAS | Only Trucks Using Bus Garage Station - Case 9A1* | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	800	7.8	8.4	27200	640	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroOENG	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	0	1.8	1.6	98550	0	0	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
STATION COSTS	Percent Imported
Compressor Cost.	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
VEHICLE COSTS	Percent Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	7800
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	205
Nitrogen Oxides (NOx)	750
Particulate Matter (PM)	7800
Sulfur Oxides (SOx)	7200

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	272
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	35
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage · Case 1A w 33% Decline in Diesel Price	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.10
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.15

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 33% Decline in Diesel Price	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($322,570)
Compressor	($648,718)	Power	($330,005)
Storage Tanks	($65,188)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($213,500)		
Installation	($593,054)		
Subtotal	($1,590,783)		($654,85[illegible])

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0		
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPINC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$5,898,047	$769,652
Subtotal		$5,898,047	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPINC	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,590,783)
Station Operation Costs	($654,850)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($4,038,416)
BENEFITS	
Fuel Savings	$5,898,047
BENEFITS MINUS COSTS	$1,859,631
BENEFIT/COST RATIO	1.46
SAVINGS (COSTS) PER LITER	$0.015
SAVINGS (COSTS) / VEHICLE	$10,566
INTERNAL RATE OF RETURN	23%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$6,408,679
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$4,011,267
EMISSIONS CHANGE EFFECTS		$769,652

BEST AVAILABLE DOCUMENT

190

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 56% Natural Gas Price Incre	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hr	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDed	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$2.50
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	35
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 56% Natural Gas Price Increase	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($322,570)
Compressor	($648,718)	Power	($330,005)
Storage Tanks	($65,188)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($213,500)		
Installation	($593,054)		
Subtotal	($1,590,783)		($654,850)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicle			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$7,012,715	$769,652
Subtotal		$7,012,715	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,590,783)
Station Operation Costs	($654,850)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($4,038,416)
BENEFITS	
Fuel Savings	$7,012,715
BENEFITS MINUS COSTS	$2,974,299
BENEFIT/COST RATIO	1.74
SAVINGS (COSTS) PER LITER	$0.025
SAVINGS (COSTS) / VEHICLE	$16,899
INTERNAL RATE OF RETURN	30%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,215,606
EMISSIONS CHANGE EFFECTS		$769,652

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Double Vehicle Conversion C	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusBiFuelDed	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroFitNG	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	5000	8000	60	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Double Vehicle Conversion Costs	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($322,570)
Compressor	($648,718)	Power	($330,005)
Storage Tanks	($65,188)	Refueling labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($213,500)		
Installation	($593,054)		
Subtotal	($1,590,783)		($654,850)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($1,100,864)	Diesel	
Tanks	($1,761,351)	Cylinder Insp.	($37,662)
Labor	($142,921)	Maintenance	$0
Subtotal	($3,005,117)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	15-Year Net Present Value of Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Average Time/Vehicle to Fill: Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,590,783)
Station Operation Costs	($654,850)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($3,005,117)
Vehicle Operations Costs	($37,662)
TOTAL	($5,497,035)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$3,605,352
BENEFIT/COST RATIO	1.66
SAVINGS (COSTS) PER LITER	$0.030
SAVINGS (COSTS) / VEHICLE	$26,485
INTERNAL RATE OF RETURN	29%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($917,370)
Vehicle Tanks	100	($1,467,793)
NET EXPORT-IMPORT REVENUE		$6,023,025
EMISSIONS CHANGE EFFECTS		$769,652

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 156% Increase in Storage C	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hr	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDed	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewElectric	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box = 1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			1
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, Cal/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
STATION COSTS	Percent Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
VEHICLE COSTS	Percent Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Lead for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 156% Increase in Storage Cost	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($[illegible]2,570)
Compressor	($648,718)	Power	($[illegible]0,005)
Storage Tanks	($167,148)	Refueling Labor	([illegible]2,274)
Dispensers			
Fast	($54,284)		
Slow	($15,940)		
Miscellaneous	($230,323)		
Installation	($639,709)		
Subtotal	($1,756,299)		($654,850)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPINO	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPINO	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,756,299)
Station Operation Costs	($654,850)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($4,203,932)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$4,898,453
BENEFIT/COST RATIO	2.17
SAVINGS (COSTS) PER LITER	$0.040
SAVINGS (COSTS) / VEHICLE	$27,832
INTERNAL RATE OF RETURN	43%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	20	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($139,290)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($104,692)
Installation	50	($290,812)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,101,750
EMISSIONS CHANGE EFFECTS		$769,652

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 79% Increase in Compressor	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

								<<<<<<<< Emissions Reduction, g/km >>>>>>>					<<<CNG Conversion Costs>>					
Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	Lead	CO	NMHC	NOx		Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14360	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14950	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	12	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed	
(Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			1
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w 79% Increase in Compressor Cost | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($322,570)
Compressor	($1,158,624)	Power	($330,005)
Storage Tanks	($65,188)	Refueling Labor	($2,274)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($213,500)		
Installation	($593,054)		
Subtotal	($2,100,490)		($654,850)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPINC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3360
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPINC	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($2,100,490)
Station Operation Costs	($654,850)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($4,548,123)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$4,554,264
BENEFIT/COST RATIO	2.00
SAVINGS (COSTS) PER LITER	$0.038
SAVINGS (COSTS) / VEHICLE	$25,876
INTERNAL RATE OF RETURN	45%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($965,354)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,503)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$6,790,851
EMISSIONS CHANGE EFFECTS		$769,652

AVAILABLE DOCUMENT

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w 25% Decrease in Daily Kilor | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline																		
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDesl	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPDIC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	73912	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box = 1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
VEHICLE COSTS	Percent Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	35
Typical Import Taxes, %	20
Cost of Land for Station (Total)	90

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base (0) =15 yr, enter 1 for 10 yr)	0

BEST AVAILABLE COPY

COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w 25% Decrease in Daily Kilometers | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($241,926)
Compressor	($497,374)	Power	($247,502)
Storage Tanks	($49,849)	Refueling Labor	($1,935)
Dispensers			
Fast	($49,686)		
Slow	($15,940)		
Miscellaneous	($165,601)		
Installation	($460,003)		
Subtotal	($1,238,453)		($491,363)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPINC	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$6,826,744	$577,235
Subtotal		$6,826,744	$577,235

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	1724
(in Standard Cubic Meters per hour)	2929
Storage Size (SCF)	98601
(in Standard Cubic Meters)	2792

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPINC	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	8.6	10.3

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,238,453)
Station Operation Costs	($491,363)
Station Gas Line Hookup Costs	($208,204)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($3,522,180)
BENEFITS	
Fuel Savings	$6,826,744
BENEFITS MINUS COSTS	$3,304,563
BENEFIT/COST RATIO	1.94
SAVINGS (COSTS) PER LITER	$0.056
SAVINGS (COSTS) / VEHICLE	$18,776
INTERNAL RATE OF RETURN	36%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$7,209,715
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($414,478)
Power Costs	30	($70,048)
Maintenance Costs	30	($68,470)
Station Storage Costs	100	($41,541)
Dispenser Costs	100	($34,688)
Miscellaneous Costs	50	($75,273)
Installation	50	($209,092)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$5,623,543
EMISSIONS CHANGE EFFECTS		$577,235

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w Double Import Taxes (40%) | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			**Diesel**					**SOx**				**PM**						
Vehicle Type 1	CTABusRetroDed	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPING	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	35
Typical Import Taxes, %	40
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

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COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Double Import Taxes (40%)	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($340,829)
Compressor	($756,837)	Power	($348,685)
Storage Tanks	($76,052)	Refueling Labor	($2,274)
Dispensers			
Fast	($63,448)		
Slow	($18,597)		
Miscellaneous	($232,909)		
Installation	($646,968)		
Subtotal	($1,794,811)		($691,788)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($642,159)	Cylinder Insp.	($37,662)
Tanks	($1,027,455)	Maintenance	$0
Labor	($115,400)		
Subtotal	($1,785,014)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPINO	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPINO	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,794,811)
Station Operation Costs	($691,788)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,785,014)
Vehicle Operations Costs	($37,662)
TOTAL	($4,517,898)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$4,524,488
BENEFIT/COST RATIO	2.01
SAVINGS (COSTS) PER LITER	$0.036
SAVINGS (COSTS) / VEHICLE	$26,848
INTERNAL RATE OF RETURN	

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,215,606
EMISSIONS CHANGE EFFECTS		$769,652

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w No Import Taxes | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	Lead	CO	NMHC	NOx		Xit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
								<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>					
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.05	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPDNG	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed:	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box = 1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	0
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] = 15 yr, enter 1 for 10 yr)	0

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COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w No Import Taxes	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($304,311)
Compressor	($540,598)	Power	($311,326)
Storage Tanks	($54,323)	Refueling Labor	($2,274)
Dispensers			
Fast	($45,320)		
Slow	($13,284)		
Miscellaneous	($194,090)		
Installation	($539,140)		
Subtotal	($1,386,755)		($617,911)

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per Hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($458,685)	Diesel	
Tanks	($733,896)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,307,981)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of: Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,386,755)
Station Operation Costs	($617,911)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,307,981)
Vehicle Operations Costs	($37,662)
TOTAL	($3,558,933)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$5,543,453
BENEFIT/COST RATIO	2.56
SAVINGS (COSTS) PER LITER	$0.046
SAVINGS (COSTS) / VEHICLE	$31,497
INTERNAL RATE OF RETURN	

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,215,606
EMISSIONS CHANGE EFFECTS		$769,652

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COMPRESSED NATURAL GAS | CTA Bus Garage · Case 1A w 33% Devaluation of Egyptian | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHr	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline	Vehicle Name																	
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDed	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	3500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroFINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.23
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.28

STATION DESIGN FACTORS

If Only Buffer Storage, Box = 1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	60
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	4.48
Time Horizon (Base [0] = 15 yr, enter 1 for 10 yr)	0

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 33% Devaluation of Egyptian Pound	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($359,087)
Compressor	($864,957)	Power	($367,364)
Storage Tanks	($86,917)	Refueling Labor	($2,274)
Dispensers			
Fast	($72,512)		
Slow	($21,254)		
Miscellaneous	($252,318)		
Installation	($700,882)		
Subtotal	($1,998,839)		($728,726)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicle			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($733,896)	Diesel	
Tanks	($1,174,234)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($2,023,530)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$13,908,896	$769,652
Subtotal		$13,908,896	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,998,839)
Station Operation Costs	($728,726)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($2,023,530)
Vehicle Operations Costs	($37,662)
TOTAL	($4,997,381)
BENEFITS	
Fuel Savings	$13,908,896
BENEFITS MINUS COSTS	$8,911,515
BENEFIT/COST RATIO	2.78
SAVINGS (COSTS) PER LITER	$0.073
SAVINGS (COSTS) / VEHICLE	$50,634
INTERNAL RATE OF RETURN	90%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$14,419,528
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($718,995)
Power Costs	30	($124,219)
Maintenance Costs	30	($121,420)
Station Storage Costs	100	($72,250)
Dispenser Costs	100	($77,942)
Miscellaneous Costs	50	($129,070)
Installation	50	($358,528)
Vehicle Conversion Kits	100	($610,051)
Vehicle Tanks	100	($976,082)
NET EXPORT-IMPORT REVENUE		$11,230,969
EMISSIONS CHANGE EFFECTS		$769,652

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w 10 Yr. Time Horizon | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDed	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPDNG	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	35
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	1

BEST AVAILABLE DOCUMENT

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 10 Yr. Time Horizon	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($243,275)
Compressor	($648,718)	Power	($248,882)
Storage Tanks	($65,188)	Refueling labor	($1,715)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($213,50[illegible])		
Installation	($593,054)		
Subtotal	($1,590,783)		($493,872)

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per Hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	TAB[illegible]wingle	11.5	12.7

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicle			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($27,052)
Labor	($90,642)	Maintenance	$0
Subtotal	($1,521,740)		($27,052)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of: Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$[illegible]864,810	$580,454
Subtotal		$6,864,810	$580,454

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,590,783)
Station Operation Costs	($493,872)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,521,740)
Vehicle Operations Costs	($27,052)
TOTAL	($3,842,070)
BENEFITS	
Fuel Savings	$6,864,810
BENEFITS MINUS COSTS	$3,022,739
BENEFIT/COST RATIO	1.79
SAVINGS (COSTS) PER LITER	$0.025
SAVINGS (COSTS) / VEHICLE	$17,175
INTERNAL RATE OF RETURN	43%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($70,438)
Maintenance Costs	30	($68,851)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($58,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,[illegible])
NET EXPORT-IMPORT REVENUE		$7,261,008
EMISSIONS CHANGE EFFECTS		$580,454

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COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Triple Labor Cost	FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPDNG	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	[illegible]	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	20	1.8	1.4	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
STATION COSTS	Percent Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
VEHICLE COSTS	Percent Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$15
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

Best Available Document

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COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Triple Labor Cost	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($322,570)
Compressor	($648,718)	Power	($330,005)
Storage Tanks	($65,188)	Refueling labor	($6,823)
Dispensers			
Fast	($54,384)		
Slow	($15,940)		
Miscellaneous	($213,500)		
Installation	($593,054)		
Subtotal	($1,590,783)		($659,398)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($550,422)	Cylinder Insp.	($112,987)
Tanks	($880,676)	Maintenance	$0
Labor	($346,200)		
Subtotal	($1,777,298)		($112,987)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDua.	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngin	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2272
(in Standard Cubic Meters per hour)	3860
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDua	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	TABusNewEngin	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,590,783)
Station Operation Costs	($659,398)
Station Gas Line Hookup Costs	($208,623)
Vehicle Completion Costs	($1,777,298)
Vehicle Operations Costs	($112,987)
TOTAL	($4,349,089)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$4,753,297
BENEFIT/COST RATIO	2.09
SAVINGS (COSTS) PER LITER	$0.039
SAVINGS (COSTS) / VEHICLE	$27,007
INTERNAL RATE OF RETURN	43%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($540,598)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,293)
Station Storage Costs	100	($54,323)
Dispenser Costs	100	($33,603)
Miscellaneous Costs	50	($97,045)
Installation	50	($269,570)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,215,606
EMISSIONS CHANGE EFFECTS		$769,652

Best Available Document

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w Triple Slow Fill Fraction | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline																		
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDed	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	56	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Bordc.	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
STATION COSTS	Percent Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
VEHICLE COSTS	Percent Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	35
Typical Import Taxes, %	20
Cost of Land for Station (Total)	50

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

Best Available Document

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Triple Slow Fill Fraction	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($318,205)
Compressor	($606,652)	Power	($330,005)
Storage Tanks	($56,414)	Refueling labor	($1,931)
Dispensers			
Fast	($49,686)		
Slow	($44,628)		
Miscellaneous	($203,616)		
Installation	($565,600)		
Subtotal	($1,526,596)		($650,139)

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2119
(In Standard Cubic Meters per hour)	3601
Storage Size (SCF)	112668
(In Standard Cubic Meters)	3190

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngin	12.9	13.9

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicle			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngin	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,526,596)
Station Operation Costs	($650,139)
Station Gas Line Hookup Costs	($208,506)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($3,969,402)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$5,132,985
BENEFIT/COST RATIO	2.29
SAVINGS (COSTS) PER LITER	$0.042
SAVINGS (COSTS) / VEHICLE	$29,165
INTERNAL RATE OF RETURN	47%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($505,543)
Power Costs	30	($93,398)
Maintenance Costs	30	($90,058)
Station Storage Costs	100	($47,012)
Dispenser Costs	100	($78,595)
Miscellaneous Costs	50	($92,553)
Installation	50	($257,091)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,256,188
EMISSIONS CHANGE EFFECTS		$769,652

Best Available Document

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w Half Fill Rate/Dispenser | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

		Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Gasoline																		
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDiesel	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPING	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.19
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.06	Fast fill rate>>>	8.5
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

Best Available Document

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COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Half Fill Rate/Dispenser	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($322,570)
Compressor	($647,877)	Power	($330,005)
Storage Tanks	($65,188)	Refueling Labor	($3,698)
Dispensers			
Fast	($77,897)		
Slow	($29,204)		
Miscellaneous	($219,300)		
Installation	($609,222)		
Subtotal	($1,648,708)		($656,273)

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2270
(in Standard Cubic Meters per Hour)	3856
Storage Size (SCF)	131469
(in Standard Cubic Meters)	3723

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	22.9	22.4

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of: Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,648,708)
Station Operation Costs	($656,273)
Station Gas Line Hookup Costs	($208,621)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($4,097,732)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$5,004,624
BENEFIT/COST RATIO	2.22
SAVINGS (COSTS) PER LITER	$0.041
SAVINGS (COSTS) / VEHICLE	$22,435
INTERNAL RATE OF RETURN	44%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($539,898)
Power Costs	30	($993,398)
Maintenance Costs	30	($991,293)
Station Storage Costs	100	($54,523)
Dispenser Costs	100	($89,251)
Miscellaneous Costs	50	($99,691)
Installation	50	($276,919)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,175,665
EMISSIONS CHANGE EFFECTS		$769,652

Best Available Document

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w Double Station | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	440	1.8	1.6	98550	352	36	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Bordc	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline 'n Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.13
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box = 1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

Best Available Document

COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Double Station	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($645,163)
Compressor	($1,275,199)	Power	($660,034)
Storage Tanks	($126,543)	Refueling Labor	($4,563)
Dispensers			
Fast	($83,065)		
Slow	($29,533)		
Miscellaneous	($415,186)		
Installation	($1,153,296)		
Subtotal	($3,082,822)		($1,309,761)

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	4539
(in Standard Cubic Meters per hour)	7712
Storage Size (SCF)	262937
(in Standard Cubic Meters)	7445

ESTIMATED VEHICLE FILL RATES

		Average Time/Vehicle to Fill	
Gasoline	Vehicle Name	Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPINO	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($1,100,844)	Cylinder Insp.	($75,325)
Tanks	($1,761,351)	Maintenance	$0
Labor	($230,800)		
Subtotal	($3,092,996)		($75,325)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

		15-Year Net Present Value of	
Gasoline	Vehicle Name	Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPINO	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$18,205,426	$1,539,359
Subtotal		$18,205,426	$1,539,359

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($3,082,822)
Station Operation Costs	($1,309,761)
Station Gas Line Hookup Costs	($210,355)
Vehicle Completion Costs	($3,092,996)
Vehicle Operations Costs	($75,325)
TOTAL	($7,771,258)
BENEFITS	
Fuel Savings	$18,205,426
BENEFITS MINUS COSTS	$10,434,168
BENEFIT/COST RATIO	2.34
SAVINGS (COSTS) PER LITER	$0.043
SAVINGS (COSTS) / VEHICLE	$29,643
INTERNAL RATE OF RETURN	58%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$19,226,728
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($1,062,666)
Power Costs	30	($186,802)
Maintenance Costs	30	($182,593)
Station Storage Costs	100	($105,453)
Dispenser Costs	100	($993,832)
Miscellaneous Costs	50	($188,721)
Installation	50	($524,225)
Vehicle Conversion Kits	100	($917,370)
Vehicle Tanks	100	($1,467,793)
NET EXPORT-IMPORT REVENUE		$14,497,273
EMISSIONS CHANGE EFFECTS		$1,539,359

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COMPRESSED NATURAL GAS | **CTA Bus Garage - Case 1A w Half Station Size** | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

																		VEHICLE DATA INPUTS
Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>			% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
								Lead	CO	NMHC	NOx		Kit	Tanks	Labor/Hr			
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	3
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	16	100	5	5
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDed	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroFENG	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDed	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	110	1.8	1.6	98550	88	9	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Borde.	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/	$0.05
Total Gasoline Price, Before Tax, $/	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
STATION COSTS	Percent Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
VEHICLE COSTS	Percent Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	35
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

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COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w Half Station Size	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($161,320)
Compressor	($335,534)	Power	($165,085)
Storage Tanks	($34,516)	Refueling labor	($1,362)
Dispensers			
Fast	($42,963)		
Slow	($9,141)		
Miscellaneous	($113,155)		
Installation	($314,320)		
Subtotal	($849,629)		($327,720)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($275,211)	Cylinder Insp.	($18,831)
Tanks	($440,338)	Maintenance	$0
Labor	($57,700)		
Subtotal	($773,249)		($18,831)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$4,552,177	$384,909
Subtotal		$4,552,177	$384,909

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	1138
(in Standard Cubic Meters per hour)	1933
Storage Size (SCF)	65734
(in Standard Cubic Meters)	1861

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	11.5	12.7

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($849,629)
Station Operation Costs	($327,720)
Station Gas Line Hookup Costs	($207,756)
Vehicle Completion Costs	($773,249)
Vehicle Operations Costs	($18,831)
TOTAL	($2,177,184)
BENEFITS	
Fuel Savings	$4,552,177
BENEFITS MINUS COSTS	$2,374,992
BENEFIT/COST RATIO	2.09
SAVINGS (COSTS) PER LITER	$0.039
SAVINGS (COSTS) / VEHICLE	$26,989
INTERNAL RATE OF RETURN	38%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$4,807,548
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($279,612)
Power Costs	30	($46,709)
Maintenance Costs	30	($45,657)
Station Storage Costs	100	($28,764)
Dispenser Costs	100	($43,420)
Miscellaneous Costs	50	($51,434)
Installation	50	($142,873)
Vehicle Conversion Kits	100	($229,343)
Vehicle Tanks	100	($366,948)
NET EXPORT-IMPORT REVENUE		$3,572,790
EMISSIONS CHANGE EFFECTS		$384,909

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w No Slow Fill | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

		Vehicles to Convert
Gasoline		
Vehicle Type 1	Auto Bi-Fuel	0
Vehicle Type 2	New Auto Ded.	0
Vehicle Type 3	Truck Bi-Fuel	0
Vehicle Type 4	New Truck Ded.	0
Diesel		
Vehicle Type 1	CTABusRetroDed	0
Vehicle Type 2	CTABusRetroPDC	0
Vehicle Type 3	CTABusRetroDed	0
Vehicle Type 4	CTABusNewEngine	220

VEHICLE DATA INPUTS

Gasoline	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>					<<<CNG Conversion Costs>>			% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Km/Liter					Lead	CO	NMHC	NOx		Kit	Tanks	LaborHrs			
10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
7.8	8.8	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel					**SOx**				**PM**						
1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
1.8	1.6	98550	176	0	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Border	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed	
(Residential, Commercial, Industrial)	Industrial

Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day $ x Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions		
SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent Imported
STATION COSTS	
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent Imported
VEHICLE COSTS	
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	35
Typical Import Taxes, %	20
Cost of Land for Station (Total)	30

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w/ No Slow Fill | **FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET**

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($324,309)
Compressor	($660,943)	Power	($330,005)
Storage Tanks	($68,683)	Refueling Labor	($2,875)
Dispensers			
Fast	($61,262)		
Slow	$0		
Miscellaneous	($216,183)		
Installation	($600,509)		
Subtotal	($1,607,580)		($657,189)

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	2316
(In Standard Cubic Meters per Hour)	3935
Storage Size (SCF)	138957
(In Standard Cubic Meters)	3935

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	0.0	12.2

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($550,422)	Cylinder Insp.	($37,662)
Tanks	($880,676)	Maintenance	$0
Labor	($115,400)		
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of: Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,607,580)
Station Operation Costs	($657,189)
Station Gas Line Hookup Costs	($208,657)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($4,057,586)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$5,044,801
BENEFIT/COST RATIO	2.24
SAVINGS (COSTS) PER LITER	$0.042
SAVINGS (COSTS) / VEHICLE	$28,664
INTERNAL RATE OF RETURN	45%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($550,786)
Power Costs	30	($93,398)
Maintenance Costs	30	($91,786)
Station Storage Costs	100	($57,235)
Dispenser Costs	100	($51,052)
Miscellaneous Costs	50	($98,265)
Installation	50	($272,958)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,204,957
EMISSIONS CHANGE EFFECTS		$769,652

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COMPRESSED NATURAL GAS | CTA Bus Garage - Case 1A w 30% Better Bus Fuel Economy | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

		Vehicles to Convert
Gasoline		
Vehicle Type 1	Auto Bi-Fuel	0
Vehicle Type 2	New Auto Ded.	0
Vehicle Type 3	Truck Bi-Fuel	0
Vehicle Type 4	New Truck Ded.	0
Diesel		
Vehicle Type 1	CTABusRetroDed	0
Vehicle Type 2	CTABusRetroPDIC	0
Vehicle Type 3	CTABusRetroDed	0
Vehicle Type 4	CTABusNewEngine	220

VEHICLE DATA INPUTS

Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	LaborHrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel					SOx				PM						
1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
1.8	1.5	98550	0	0	2.2	21.7	2.9	14.3	2.41	3600	4000	70	100	5	14
2.3	2.1	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Borde	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed	
(Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Full Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box = 1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	15	For fast fill>>>>	7
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.56
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	85
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

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COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 30% Better Bus Fuel Economy	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($242,695)
Compressor	($498,818)	Power	($248,290)
Storage Tanks	($49,996)	Refueling Labor	($1,935)
Dispensers			
Fast	($49,686)		
Slow	($15,940)		
Miscellaneous	($166,051)		
Installation	($461,252)		
Subtotal	($1,241,743)		($492,920)

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	1729
(in Standard Cubic Meters per hour)	2938
Storage Size (SCF)	98914
(in Standard Cubic Meters)	2801

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPING	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	8.6	10.3

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles			
Conversion Kit	$0	Gasoline	
Tanks	$0	Cylinder Insp.	$0
Labor	$0	Maintenance	$0
Diesel Vehicles			
Conversion Kit	($550,422)	Diesel	
Tanks	($880,676)	Cylinder Insp.	($37,662)
Labor	($115,400)	Maintenance	$0
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of: Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPING	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$7,068,719	$769,652
Subtotal		$7,068,719	$769,652

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,241,743)
Station Operation Costs	($492,920)
Station Gas Line Hookup Costs	($208,208)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($3,527,031)
BENEFITS	
Fuel Savings	$7,068,719
BENEFITS MINUS COSTS	$3,541,688
BENEFIT/COST RATIO	2.00
SAVINGS (COSTS) PER LITER	$0.039
SAVINGS (COSTS) / VEHICLE	$20,123
INTERNAL RATE OF RETURN	38%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS

FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$7,397,845
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($415,682)
Power Costs	30	($70,271)
Maintenance Costs	30	($68,687)
Station Storage Costs	100	($41,663)
Dispenser Costs	100	($54,688)
Miscellaneous Costs	50	($75,478)
Installation	50	($209,660)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$5,269,136
EMISSIONS CHANGE EFFECTS		$769,652

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COMPRESSED NATURAL GAS | CTA Bus Garage Case 1A w 29% More Time for Fast Fill | **FLEET COST AND BENEFIT ESTIMATE MODEL INPUT SHEET**

VEHICLE DATA INPUTS

Gasoline	Vehicle Name	Vehicles to Convert	Gasoline Km/Liter	CNG Km per Liter equivalent	Daily Km x Days Service	Vehicles in Operation	Slow Fill Vehicles	<<<<<<< Emissions Reduction, g/km >>>>>>> Lead	CO	NMHC	NOx		<<<CNG Conversion Costs>> Kit	Tanks	Labor Hrs	% km on CNG	Years to Convert	Cyl Insp Hrs/Yr
Vehicle Type 1	Auto Bi-Fuel	0	10.6	11.6	14960	0	0	0.056	6.5	2.9	0.2		200	350	13	80	5	3
Vehicle Type 2	New Auto Ded.	0	10.6	11.2	14960	0	0	0.07	25.2	3.2	0.9		200	700	16	100	5	3
Vehicle Type 3	Truck Bi-Fuel	0	7.8	8.4	27200	0	0	0.06	7.9	2.2	0.2		200	700	16	80	5	6
Vehicle Type 4	New Truck Ded.	0	7.8	8.2	27200	0	0	0.08	29.8	2.4	1.04		300	1700	18	100	5	6
Diesel			Diesel					SOx				PM						
Vehicle Type 1	CTABusRetroDual	0	1.8	1.4	98550	0	0	0.9	-11.3	-2.2	7.4	1.90	2500	3200	64	70	5	11
Vehicle Type 2	CTABusRetroPINC	0	1.8	1.6	98550	0	0	1.5	20.4	1.9	11.2	2.36	5000	3200	64	85	5	11
Vehicle Type 3	CTABusRetroDual	0	1.8	1.5	98550	0	0	1.7	21.7	2.2	11.0	2.41	3600	4000	70	100	5	14
Vehicle Type 4	CTABusNewEngine	220	1.8	1.6	98550	176	18	1.7	21.7	2.2	11.0	2.41	2500	4000	30	100	5	14

FUEL RELATED INPUTS

Conditions (Prices, Gas Pressure) at Station Borde	
Natural Gas Price $/(1000 cubic feet)	$1.60
Natural Gas MBTU per cubic foot	1133
Gas Pressure and Rate Type Assumed	
Pressure in Bar	30
Distance to Major Pipeline in Meters	1500
Electricity Price $/kWh	$0.05
Type of Electric Rate Assumed (Residential, Commercial, Industrial)	Industrial
Cost of Continuing Use of Current Fuels	
Bulk Gasoline Price, $/liter	$0.13
Gasoline Lead Content, g/liter	
Delivery/Dispensing Costs, $/l	$0.05
Total Gasoline Price, Before Tax, $/l	$0.19
Diesel Price, $/liter	$0.15
Diesel Sulfur Content, %	
Delivery/Dispensing Costs, $/l	$0.05
Total Diesel Price, Before Tax	$0.20

STATION DESIGN FACTORS

If Only Buffer Storage, Box =1, Otherwise Set = 0			1
Cost of Storage as Fraction of ASME Rated Storage			0.39
Fraction of Gas Recoverable from Storage			0.5
Hours available for slow fill >>	13	For fast fill>>>>	9
Slow fill rate, CM/minute >>>	0.12	Fast fill rate>>>	17
Compressor Cost Function Intercept Term			31394
Compressor Cost Function Slope Coefficient			493
Compressor Cost Factor, > 6 Bar enter 0.56, 1 if less			0.55
Hours/day for Compressor Maintenance			1

Fraction Recoverable From Storage Varies: 0.40 to 0.55

Compressor Cost Functions

SCFM per Unit	Intercept Term	Slope Coefficient
50	23820	977
75	26968	637
100	31394	493

IMPORT COST SHARES

COST ITEM	SHARE
	Percent
STATION COSTS	Imported
Compressor Costs	100
Power Costs	30
Maintenance Costs	30
Station Storage Costs	100
Dispenser Costs	100
Miscellaneous Costs	50
Installation	50
	Percent
VEHICLE COSTS	Imported
Vehicle Conversion Kits	100
Vehicle Tanks	100

VALUE OF EMISSIONS REDUCTIONS

	$/tonne
Lead	500
Carbon Monoxide (CO)	22
Non Methane Hydrocarbons (NMHC)	225
Nitrogen Oxides (NOx)	560
Particulate Matter (PM)	650
Sulfur Oxides (SOx)	520

MISCELLANEOUS ECONOMIC INPUTS

Real Discount Rate, %	10
Labor Cost, $/hr	$5
Typical Import Taxes, %	20
Cost of Land for Station (Total)	$0

MISCELLANEOUS ECONOMIC INPUTS

Days of Fleet/Station Operation	365
Exchange Rate	3.37
Time Horizon (Base [0] =15 yr, enter 1 for 10 yr)	0

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COMPRESSED NATURAL GAS	CTA Bus Garage - Case 1A w 29% More Time for Fast Fill	FLEET COST AND BENEFIT ESTIMATE MODEL OUTPUT SHEET

STATION CAPITAL & ANNUAL OPERATIONS COSTS

CATEGORY	Initial Costs (NPV)	CATEGORY	Annual Costs (15-Year NPV)
Land	$0	Maintenance	($315,248)
Compressor	($524,139)	Power	($330,005)
Storage Tanks	($50,477)	Refueling Labor	($2,154)
Dispensers			
Fast	($49,216)		
Slow	($29,204)		
Miscellaneous	($175,702)		
Installation	($488,060)		
Subtotal	($1,316,797)		($647,407)

VEHICLE CAPITAL & OPERATIONS COSTS

VEHICLES	Initial Cost		15-Year NPV
Gasoline Vehicles		Gasoline	
Conversion Kit	$0	Cylinder Insp.	$0
Tanks	$0	Maintenance	$0
Labor	$0		
Diesel Vehicles		Diesel	
Conversion Kit	($550,422)	Cylinder Insp.	($37,662)
Tanks	($880,676)	Maintenance	$0
Labor	($115,400)		
Subtotal	($1,546,498)		($37,662)

VEHICLE FUEL SAVINGS & EMISSION BENEFITS

Gasoline	Vehicle Name	15-Year Net Present Value of Fuel Costs	Emissions
Vehicle Type 1	Auto Bi-Fuel	$0	$0
Vehicle Type 2	New Auto Ded.	$0	$0
Vehicle Type 3	Truck Bi-Fuel	$0	$0
Vehicle Type 4	New Truck Ded.	$0	$0
Diesel			
Vehicle Type 1	CTABusRetroDual	$0	$0
Vehicle Type 2	CTABusRetroPINO	$0	$0
Vehicle Type 3	CTABusRetroDed	$0	$0
Vehicle Type 4	CTABusNewEngine	$9,102,386	$769,652
Subtotal		$9,102,386	$769,652

STATION DESIGN VALUE ESTIMATES

Compressor Capacity (SCF per Minute)	1823
(in Standard Cubic Meters per hour)	3096
Storage Size (SCF)	99945
(in Standard Cubic Meters)	2830

ESTIMATED VEHICLE FILL RATES

Gasoline	Vehicle Name	Average Time/Vehicle to Fill: Slow (Hours)	Fast (Minutes)
Vehicle Type 1	Auto Bi-Fuel	0.0	0.0
Vehicle Type 2	New Auto Ded.	0.0	0.0
Vehicle Type 3	Truck Bi-Fuel	0.0	0.0
Vehicle Type 4	New Truck Ded.	0.0	0.0
Diesel			
Vehicle Type 1	CTABusRetroDual	0.0	0.0
Vehicle Type 2	CTABusRetroPINO	0.0	0.0
Vehicle Type 3	CTABusRetroDed	0.0	0.0
Vehicle Type 4	CTABusNewEngine	16.0	12.5

FLEET OWNER PERSPECTIVE

COSTS	NPV
Station Completion Costs	($1,316,797)
Station Operation Costs	($647,407)
Station Gas Line Hookup Costs	($248,279)
Vehicle Completion Costs	($1,546,498)
Vehicle Operations Costs	($37,662)
TOTAL	($3,756,644)
BENEFITS	
Fuel Savings	$9,102,386
BENEFITS MINUS COSTS	$5,345,742
BENEFIT/COST RATIO	2.42
SAVINGS (COSTS) PER LITER	$0.044
SAVINGS (COSTS) / VEHICLE	$30,374
INTERNAL RATE OF RETURN	52%

EGYPTIAN GOVERNMENT PERSPECTIVES

NET EXPORT MINUS IMPORT EFFECTS		
FUEL EXPORT REVENUES (OR IMPORT SAVINGS) ALLOWED		15 yr NPV SAVINGS
Diesel Fuel Use Avoided		$9,613,019
Gasoline Fuel Use Avoided		$0
CAPITAL IMPORT COSTS	Percent Imported	15 yr NPV COSTS
Compressor Costs	100	($436,782)
Power Costs	30	($93,398)
Maintenance Costs	30	($89,221)
Station Storage Costs	100	($42,064)
Dispenser Costs	100	($65,350)
Miscellaneous Costs	50	($79,864)
Installation	50	($221,846)
Vehicle Conversion Kits	100	($458,685)
Vehicle Tanks	100	($733,896)
NET EXPORT-IMPORT REVENUE		$7,391,912
EMISSIONS CHANGE EFFECTS		$769,652

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Appendix 3:

Contact List

LIST OF PERSONS CONTACTED

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  Director, Environment Office
  Tel: 357-3277/8

- Mr. Mark Madland
  Environment Office

- Eng. Saad Abdalla
  Consultant Engineer, Environment Office
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- Mr. Richard Steelman
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- Mr. Robert Rose,
  Director, Engineering Office
  Tel: 357-3352

inistry of Petroleum
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El Mokhayam El Dayem Street
asr City, Cairo, Egypt.

- Eng. Sanaa El Banna
  Under-Secretary of Technical Affairs
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- Eng. Hazem Mohammad Amin Hammad
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- Dr. Mohie El-Din Selim
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- Dr.Ibrahim Abdel Gelil
  Newly Appointed Chairman
  (Currently on a U.S. Fellowship Program and is expected to return on June 28, 1994)
- Dr. Hani A. Alnakeeb
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  Tel: 616576, 610153
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- Eng. Abdul Wahab Barakat
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- Ms. Samia Guirguis Hanna
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- Mr. Hamid Korkar, Economist
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Ministry of Transportation
Transportation Planning Authority
.05 Kasr Aini Street
:airo.

- Dr. Ahmed Eisawi Saleh
  Vice Chairman
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Egypt Gas, Natural Gas Projects Company,
, Midan Kasr El Dobra,
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- Eng. Abdel Hamid Abubakr
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- Dr. Mahmoud G. El-Din Badran
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- Mr. Constanti Muzio
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- Ms. Laila Darwish Said
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  Industry & Energy Department
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- Mr. A.S. El-Mekkawy
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  Egypt Energy Sector Assessment Project
  Tel: 202 473 8895

- Mr. Viren Sirohi
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- Mr. Hatem Khairy
  General Manager

- Eng. Mostafa Ismail Mostafa
  General Maintenance Department
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- Eng. Ihab Ahmed
  CNG Gas Station Manager

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Cairo, Egypt.

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- Farouk M. Mohamedain

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- Mr. Hady Tarrab
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  Fax: 570 3515

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- Mr. Essam Hassaby
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  Gesr El Suez Garage
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- Eng. Ahmed Mohamed Shaban
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- Eng. Abdel-Aziz Derar
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Appendix 4: Selected Additional Information on Fuels and Vehicle Population

DOMESTIC PRICES OF PETROLEUM PRODUCTS AND NATURAL GAS IN EGYPT 1986/87-1992/93

(LE/TON)

ITEM	AVERAGE PRICES			14/07/93
	1986/87	1989/90	1992/93	
PREMIUM GASOLINE	420	595	1400	1400
REGULAR GASOLINE	350	525	1260	1260
GAS OIL	40	93	420	480
DIESEL FUEL	34	81	359	421.2
FUEL OIL	11	37.5	115	130
NATURAL GAS	28	41	134	152

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March 1994

Typeplace	Government	Government	Public sector	Cannon	Commerce &Tourism	Capers Diplomatic	Motor Cycles	Agricultural T.	Trailers	Trucks	Bus				On call	Taxi	Caravan	Private	Total
											School	Tourism	Private	Public					
Cairo	3859	7436	33421	8575	2806	5400	92577	385	6088	84524	8024	3027	4669	4276	572	41364	264	435163	736180
Alexandria	207	8165	7609		2809		85402	1897	12546	53887	217	776	6023	1176	41	29582	56	155736	388539
Abu Hadur		232	1222	13936	1439	982												7289	85010
Port Said	583	446	1258	127	328		4035	14	598	2529	6	40	104	95	11	3773	2	14234	20866
Suez	509	180	637	89979	4		5199	73	446	1652		14	374	203	4	3313		10188	112907
Ismailia	623	511	3105		532		6433	832	895	8573	10	3	317	121	1	4290	2	10251	36580
Damietta	1179	291	827		147		13850	818	398	2033	2	13	49	20	3	3067		8169	34420
Sharkia	382	1985	535		395		21645	2265	1415	28647	6	60	1308	590	4	7536	4	18860	79524
Dakahlia	447	2395	162		590		22076	600	3473	23592	48	30	825	995	6	14361	4	23759	92463
Behera	1778	869	1330	4	81		6037	4506	4439	21948	16	34	138	369	1	6636		7651	57921
Gharbia	2340	6003	4847		316		30314	8396	2592	21817	13	69	807	1129	5	10589		28486	93653
Menufia	549	1241	155		197		23753	1886	2869	21591	1	28	152	582	2	9588	1	11484	63251
Kafr El-Sheikh	474	1274	389	56	28		4610	455	650	10861	1	2	18	454	1	5004		6455	30605
Kalyoubia	730	688	[illegible]	9	250		26350	382	1588	18208	93	290	728	232	26	13475		17400	83950
Giza	1963	3737	1798		319		37448	403	1709	34132	425	310	2044	370	226	27825	54	146893	256784
Fayoum	515	764	360		93		16200	1220	1282	4984		5	30	222	3	3469		7824	36552
Beni Suef	328	499	182		31		9241	139	184	7600	2	18	45	183	4	2460		6704	26948
Minia	824	2084	297		128		[illegible]	[illegible]	488	12668	20		191	282	2	1427		7375	30609
Assiut	552	572		7	135		7571	1099	729	18990	14	[illegible]	168	312	18	6747		10784	38828
Sohag	450	1544	475		137		6843	366	399	9056	5	21	[illegible]	[illegible]	4	[illegible]		6068	28911
Qena	1058	615	561	459	613		9030	555	489	8892	6	197	245	207	16	6340		5530	34011
Aswan	313	357	1150	43	120		6066	125	62	4504		138	239	36	2	5213	3	3494	22214
Aswan	299	222	1115		32		356	7	138	4203		1	18	5		815		979	7170
Red Sea	766	271	246	242	18		246	11	135	2317		3	61	32		1006		1469	7403
New Valley	595	584	213		12		1666	252	239	824			4	39	5	282		432	4935
North Sinai	646	102	98	127	35		833	406	30	3460		5	22	37		862	1	1829	8785
South Sinai	203	378	63		22		158	3	30	1129		33	48	21	1	435		440	2807
Total	22894	36277	64303	113854	12252	6382	363886	19735	43798	308222	1013	5154	17895	11448	958	213539	392	945946	2265250

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Ministry of Interior
General Traffic Dept.
Statistic Dept.

Type/place	Governorate	Governmental	Public Secor	Custom	Commun. &Temp.	Corps Diplomatic	Motorcycles	Agricultural T.	Trailors	Trucks	School	Buses Tourism	Buses Private	Public	On call	Taxi	Caravane	Private	Total
Cairo	3066	6052	39587	8717	2769	4754	90566	291	6362	82200	926	2568	7902	4024	563	41760	242	418873	721231
Alexandria	158	930	7135	-	2635	-	14417	1197	12268	48527	186	660	4596	1114	38	27194	51	148010	269116
Alex.Harbor	-	197	1170	16003	2667	735	-	-	-	4	-	-	-	-	-	-	-	5193	24969
Port Said	180	122	802	209	330	-	3797	4	436	2115	7	28	55	91	9	3633	2	13516	25344
Suez	406	98	581	83183	180	-	4680	73	396	1258	-	13	358	166	4	3078	-	8606	103128
Ismailia	477	401	1367	-	610	-	6253	1095	1109	8676	6	3	292	115	2	4186	2	10134	34728
Damietta	970	163	797	-	97	-	10764	136	377	6069	2	7	14	69	3	2991	-	6729	28168
Sharkia	329	1062	5208	-	341	-	16835	2100	1131	17238	6	55	586	555	-	6223	4	14916	66585
Dakahlia	428	724	1700	-	489	-	20269	890	3028	21465	47	27	38	395	5	10947	4	20075	80531
Behera	1760	675	1536	6	83	-	7640	4387	4230	20970	14	29	107	369	-	6125	-	7282	55222
Gharbia	712	7372	7162	-	302	-	20655	1781	2547	20034	11	55	17	1115	4	10319	-	20562	93448
Monofia	676	570	512	-	107	-	21952	2116	2419	11201	1	22	47	634	2	9[illegible]	1	11168	60613
Kalyoubia	332	958	380	81	[illegible]	-	4408	478	641	10266	2	1	11	494	-	4776	-	6364	29201
Gizeh	545	435	2675	50	752	-	25420	410	1502	19510	61	221	356	196	16	13816	-	17280	83334
Fayoum	1528	2709	5840	-	303	-	34156	383	1140	33993	405	201	1334	367	199	26972	51	35415	244[illegible]
Beni Suef	605	753	367	2	[illegible]	-	16154	1393	1370	5009	-	-	50	222	3	3498	-	7287	36703
Menia	297	423	267	-	22	-	7872	78	101	5633	15	19	50	125	4	2054	-	5305	22345
Assuit	727	1078	853	-	118	-	6265	796	449	10339	16	3	67	217	3	1441	-	7257	30229
Sohag	400	645	1474	7	135	-	9306	1129	710	9490	14	30	159	312	18	6451	-	10049	40514
Quena	400	1076	485	-	134	-	7005	382	393	8632	7	17	13	97	4	4066	-	6124	28935
Aswan	691	1020	616	474	413	-	8420	494	452	7147	2	126	149	236	16	6007	-	5101	31267
Matrouh	283	637	1356	43	102	-	5027	126	53	3946	-	124	215	69	2	4625	3	3086	20596
Red Sea	222	166	130	-	26	-	366	8	128	3076	-	-	15	5	-	829	-	917	6683
New Valley	230	196	327	242	18	-	715	-	129	2020	3	17	65	108	-	825	-	1208	6103
North Sinai	295	473	242	-	5	-	1754	308	264	833	-	-	4	37	3	194	-	411	4032
South Sinai	397	363	136	96	34	-	775	417	20	3495	-	5	8	38	-	806	2	1881	8472
Total	240	157	217	-	30	-	107	3	24	1074	-	25	51	-	1	337	-	380	2646
	16227	300448	62930	108092	12903	5489	346570	20475	41767	366810	1731	4256	16663	11167	901	202333	362	893129	21[illegible]747

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