Liquefied Petroleum Gas Vehicle Projects to Reduce Greenhouse Gas Emissions:

A Resource Guide for Project Development

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National Energy Technology Laboratory (NETL)

By:
Science Applications International Corporation (SAIC)
Climate Change Services

Disclaimer

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National Energy Technology Laboratory (NETL)
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
www.netl.doe.gov

By

Science Applications International Corporation (SAIC)
Climate Change Services

With Contributions From:
Josh Radoff, SAIC-Lead Author
Orestes Anastasia, Nancy Checklick, Vivianne Couts, Julie Doherty,
Jette Findsen, Sarah Goldstein, and Laura Gehlin, SAIC; and
Richard Bechtold, Independent Consultant

Reviewed by:

Jim Ekmann, NETL
Melissa Chan, NETL

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Acronyms Used in This Report

1605(b)	U.S. Department of Energy's Voluntary Reporting of Greenhouse Gases Program
ADV	Advanced Three-Way Catalyst
AFV	Alternative Fuel Vehicle
AIJ	Activities Implemented Jointly Pilot Phase
ASME	American Society of Mechanical Engineering
AT PZEV	Advanced Technology Partial Zero-Emission Vehicle
Btu	British Thermal Units
CAF	Andean Development Fund
CARB	California Air Resources Board
CERUPT	Certified Emission Reductions Procurement Tender
CDM	Clean Development Mechanism
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CDM	Clean Development Mechanism
CG	Conventional Gasoline
CV	Conventional Vehicle
CCX	Chicago Climate Exchange
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
E10	A Mixture of 10 percent Ethanol and 90 percent Gasoline
E85	A Mixture of 85 percent Ethanol and 15 percent Gasoline
EF	Emission Factor
EIA	Energy Information Administration
EPAct	Energy Policy Act of 1992
E.O.	Executive Order
EPA	U.S. Environmental Protection Agency
ERUPT	Emission Reductions Procurement Tender
ETW	Early Three-Way Catalyst
EU	European Union
EV	Electric Vehicle
GGAP	Australia's GHG Abatement Program
GHG	Greenhouse Gas
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model
GWP	Global Warming Potential
GVW	Gross Vehicle Weight
HC	Hydrocarbon
HEV	Hybrid-Electric Vehicle
IFC	International Finance Corporation
ILEV	Inherently Low-Emission Vehicle
INCaF	International Finance Corporation -- Netherlands Carbon Facility
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
IRS	Internal Revenue Service
JI	Joint Implementation
LEV	Low-Emission Vehicle
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
MPG	Miles Per Gallon

MPG-E	Miles Per Gallon Equivalent
NFPA 58	National Fire Protection Agency Standard 58
NGV	Natural Gas Vehicle
NMOG	Non-Methane Organic Gas Standard
NO_X	Nitrogen Oxides (unspecified)
N_2O	Nitrous Oxide
NPV	Net Present Value
OCC	Oxidation Catalyst Systems
OEM	Original Equipment Manufacturer
PCF	Prototype Carbon Fund
PERRL	Canada's Pilot Emission Removals, Reductions and Learning Initiative
P.L.	Public Law
PM	Particulate Matter
PTW	Pump to Wheel
PZEV	Partial Zero-Emission Vehicle
RFG	Reformulated Gasoline
SULEV	Super-Ultra-Low-Emission Vehicle
SUV	Sport Utility Vehicle
SULEV	Super Ultra-Low-Emission Vehicle
TPES	Total Primary Energy Consumption
USIJI	U.S. Initiative on Joint Implementation
ULEV	Ultra-Low-Emission Vehicle
UNC	Uncontrolled
UNFCCC	United Nations Framework Convention on Climate Change
USBC	United States Bakery Company
WWF	World Wildlife Fund
WTP	Well to Pump
ZEV	Zero-Emission Vehicle

Useful Charts / Conversion Factors

Unit-of-Measure Equivalents

Unit	Equivalent	
Kilowatt (kW)	1,000	Watts
Megawatt (MW)	1,000,000	Watts
Gigawatt (GW)	1,000,000,000	Watts
Terawatt (TW)	1,000,000,000,000	Watts
Gigawatt	1,000,000	Kilowatts
Thousand Gigawatts	1,000,000,000	Kilowatts
Kilowatthours (kWh)	1,000	Watthours
Megawatthours (MWh)	1,000,000	Watthours
Gigawatthours (GWh)	1,000,000,000	Watthours
Terawatthours (TWh)	1,000,000,000,000	Watthours
Gigawatthours	1,000,000	Kilowatthours
Thousand Gigawatthours	1,000,000,000	Kilowatthours

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Electric Power Division, http://www.eia.doe.gov/cneaf/electricity/page/prim2/charts.html.

Metric Conversion

Type of Unit	U.S. Unit	Times	Conversion Factor[a]	Equals	Metric Unit
Mass	short tons (2,000 lb)	x	0.907 184 7	=	metric tons (t)
	pounds (lb)	x	0.453 592 37[b]	=	kilograms (kg)
Volume	barrels of oil (bbl)	x	0.158 987 3	=	cubic meters (m3)
	cubic feet (ft3)	x	0.028 316 85	=	cubic meters (m3)
	U.S. gallons (gal)	x	3.785 412	=	liters (L)
Energy	British thermal units (Btu)	x	1,055.055 852 62[bc]	=	joules (J)

[a] Spaces have been inserted after every third digit to the right of the decimal for ease of reading. Most metric units belong to the International System of Units (SI), and the liter and metric ton are acceptable for use with the SI units.
[b]Exact conversion.
[c]The Btu used in this table is the International Table Btu adopted by the Fifth International Conference on Properties of Steam, London, 1956.
Sources: General Services Administration, Federal Standard 376B, *Preferred Metric Units for General Use by the Federal Government* (Washington, DC, January 27, 1993), pp. 9-11, 13, and 16. National Institute of Standards and Technology, Special Publications 330, 811, and 814. American National Standards Institute/Institute of Electrical and Electronic Engineers, SVIEEE Std 268-1992, pp. 28 and 29, http://www.eia.doe.gov/cneaf/electricity/page/prim2/charts.html.

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Overview

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) prepared this resource guide, *Liquefied Petroleum Gas Vehicle Projects to Reduce Greenhouse Gas Emissions: A Resource Guide for Project Development*, to provide propane vehicle fleet owners and/or operators, policy makers focusing on alternative fuel vehicles and climate change, greenhouse gas (GHG) emission reduction project developers, national climate change entities, and other public and private sector representatives worldwide with a guide on how to estimate and document the greenhouse gas (GHG) emission reduction benefits and/or penalties of LPG projects. Of the 1,705 projects reported to the DOE Energy Information Administration (EIA) 1605(b) Voluntary Reporting of Greenhouse Gases Program in the most recent reporting year, 2001, only 2 were LPG vehicle projects. There are currently no liquefied petroleum gas (LPG) vehicle projects reported as part of the U.N. Framework Convention on Climate Change (UNFCCC) Activities Implemented Jointly (AIJ) Pilot Phase and no record of private transactions for GHG emission reductions from LPG vehicle projects in the emerging GHG market. A few GHG transactions based on transport-related emission reduction activities took place in 2001 and 2002, representing about 4 percent of total volume traded through projects.[1] These trades indicate a growing interest in transportation activities as a market-based GHG mitigation option, which may result in an increased interest in the use of LPG vehicle projects to reduce GHG emissions. However, guidance for the reporting and quantification of emission benefits from LPG vehicles will still need to be developed

The main purpose of this manual is to provide information on quantifying and documenting GHG emission reductions from LPG vehicle projects for submission/documentation in the above listed programs. This publication also provides a description of an LPG vehicle fleet in Pucallpa, Peru and its potential to reduce GHGs as an example of an LPG vehicle GHG emission reduction project in the developing world.

The transportation sector is a major contributor to GHG emissions in the U.S. and the rest of the world. Motor vehicles emit over 900 million metric tons of CO_2 worldwide each year, accounting for more than 15 percent of global fossil fuel-derived CO_2 emissions.[2] In the industrialized world, 20-25 percent of GHG emissions come from the transportation sector, and the share of transport-related emissions continues to grow.[3] The inclusion of the transportation sector in an emerging GHG reduction policy would help reduce or slow the emissions growth from this sector while providing transportation stakeholders with added incentive to introduce cleaner and more efficient transportation options.

Over the past several years, a variety of policies and programs to address the issue of climate change have been implemented around the world. While each initiative differs in scope and methodology, many of them use or are moving towards the use of market-based mechanisms to reduce emissions in an economically efficient manner. As a result, a number of different and sometimes isolated markets for the purchase and trade of GHG emission allowances and project-based emission reductions have emerged. These markets continue to grow as countries become more familiar with the concept of emissions trading and begin to link the various programs across national and regional boundaries. The emergence of these GHG markets may provide developers

[1] Frank Lecocq and Karan Capoor, "The State and Trends of the Carbon Market," PowerPoint presentation prepared for the World Bank PCF *Plus*. October 2002.

2 "Proceed With Caution: Growth in the Global Motor Vehicle Fleet," World Resources Institute, <http://www.wri.org/trends/autos.html>, (31 March 2003).

3 "Good Practice Greenhouse Abatement Policies: Transport Sector," OECD and EIA Information Papers prepared for the Annex I Expert Group on the UNFCCC, OECD and IEA, Paris, November 2000. Emissions exclude land-use change and forestry, and bunker fuels.

of transportation projects with additional funding for the development of innovative and new activities that lead to the reduction of GHG emissions from the transportation sector.

Opportunities to reduce GHG emissions from the transportation sector could take the form of fuel switching from conventional gasoline and diesel to less carbon-intensive fuels, improvements in vehicle engine efficiency in terms of vehicle miles traveled per gallon of fuel, or reductions in vehicle miles traveled through measures such as improved public transportation or increased vehicle occupancy. Governments may encourage or regulate these activities in three general ways:

1) Increased government regulation or funding to improve vehicle technologies, promote public transportation, and reduce travel demand.

2) Voluntary initiatives to increase vehicle efficiency and reduce demand for travel.

3) The creation of programs to report or purchase project-related GHG emission reductions or establishment of a market for GHG emission reductions—whether through mandatory or voluntary participation—wherein GHG emission reductions become valued as a commodity.

The third option, involving activities to purchase or trade GHG emission reductions, represents a more recent approach to reducing emissions from the transportation sector and less information is thus available on the procedures for developing and accounting for the potential GHG emissions benefits of transport activities. This resource guide is intended to advance the discussion in this area and facilitate the development of new and innovate transportation projects that reduce GHG emissions. As LPG vehicles typically result in significant GHG emissions benefits compared to that of similar conventional gasoline vehicles, the resource guide will focus on the procedures for estimating the GHG benefits of LPG vehicles and will highlight some of the most important methodological issues that must be addressed in order to design and develop a successful, market-worthy GHG emission reduction project.

This resource guide is one in a series developed by NETL intended for vehicle fleet owners and project developers interested in undertaking alternative fuel vehicle projects, reducing GHG emissions, and taking advantage of potential funding opportunities available through the emerging GHG reduction market. Previous guidebooks have focused on GHG accounting procedures for compressed natural gas and electric and hybrid-electric vehicles.[4]

The resource guide is organized as follows:

- Chapter 1 describes the energy properties of LPG and provides an overview of the production processes involved in preparing LPG, the demand and supply of LPG, and the cost of the fuel.

- Chapter 2 presents the various LPG vehicle technology options—both conversions and new vehicles—and the refueling infrastructure that are currently available on the market. The chapter also includes an overview of vehicle cost, fuel demand and prices, and provides a brief LPG vehicle fleet example.

[4] Orestes Anastasia, Nancy Checklick, Vivianne Couts, Julie Doherty, Jette Findsen, Laura Gehlin, and Josh Radoff, *Greenhouse Gas Emission Reductions and Natural Gas Vehicles: A Resource Guide on Technology Options and Project Development*, National Energy Technology Laboratory, September 2002; and Orestes Anastasia, Nancy Checklick, Vivianne Couts, Julie Doherty, Jette Findsen, Laura Gehlin, and Josh Radoff, *Battery-Powered Electric and Hybrid Electric Vehicle Projects to Reduce Greenhouse Gas Emissions: A Resource Guide for Project Development*. National Energy Technology Laboratory, July 2002.

- Chapter 3 provides an overview of the emerging GHG market, emissions trading, and the types of programs available for purchasing and reporting GHG emission reductions. The chapter highlights opportunities for transportation projects to realize GHG emission reductions and earn recognition and potential crediting for those reductions within the larger climate change policy frameworks.

- Chapter 4 describes the GHG emissions resulting from the use of LPG in vehicles. The chapter also provides an overview of some of the various models and approaches for estimating emission benefits from different types of vehicles and using different types of data, such as vehicle miles traveled or fuel records. The chapter relies heavily on the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model from Argonne National Laboratory, but other quantification approaches are examined as well.

- Chapter 5 explains the specific procedures involved in quantifying the GHG emission benefits of transportation projects, and developing and designing GHG reduction projects in order to register, trade or earn recognition for the achieved reductions. The chapter focuses on procedures that are common among the various GHG reporting and trading programs around the globe, including additionality evaluation and GHG emission baseline development.

- Finally, Chapter 6 illustrates how the various GHG quantification procedures can be applied by presenting a case study in Peru, which is based on current vehicle and fuel use in the city of Pucallpa. As part of this case study, we analyze the potential GHG reductions that could be achieved if a project developer converted up to 20,000 gasoline-fueled motorcycle-taxis (mototaxis) to run on LPG. Several difference project and baseline scenarios are presented, and the number of qualifying vehicles and estimates of emission reductions will depend on which scenario is used. Replacing gasoline-fueled mototaxis with LPG vehicles in Peru provides a significant opportunity to reduce GHGs; a potential 20-25 percent emission reduction potential may be achieved.

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1 LPG Composition and Energy Content

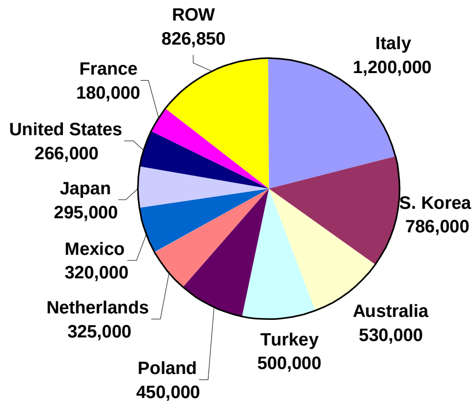
1.1 LPG Overview

Liquefied petroleum gases (LPG or LP Gas) are light hydrocarbons containing no sulfur and having high octane ratings, which makes them very good alternative fuels for spark ignition engines. For vehicle use in the U.S., an LPG specification has been developed—known as HD-5 LPG or just "LPG"—that requires 90 percent propane minimum, 2.5 percent butane maximum, and 5 percent propylene maximum. LPG is one of several liquefied petroleum gases whose main distinguishing characteristic is that it becomes a liquid when put under modest pressures (less than 300 psi and typically between 100 and 200 psi).

In Europe, LPG is typically a mixture of propane and butane (up to 50 percent butane) and is called "Autogas." Worldwide, about 60 percent of LPG is extracted during the production of natural gas and 40 percent is produced when crude oil is refined.[5] In the U.S., 48 percent of the 4.11 million barrels of LPG produced per day in 2002 was derived from natural gas refining while 52 percent came from petroleum refining.[6] LPG is most commonly used for home cooking and heating, but it is used in industrial processes as well. LPG is naturally odorless, so an odorant is added for safety purposes similar to the practice used for natural gas.

LPG is the alternative vehicle fuel used in highest quantity throughout the world. There are about 5.7 million vehicles operating on LPG in 38 countries (see Figure 1-1). These vehicles are served by approximately 31,000 refueling stations. LPG is also the alternative fuel used in the largest volume in the U.S., with an estimated rate of consumption of 243 million gallons per year—representing two-thirds of all alternative fuel used in the U.S. in 2000.[7] LPG has been used as a vehicle fuel in the U.S. since the 1940s.

Figure 1-1. LPG Vehicles in Use Worldwide[8]



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[5] "Where LPG Comes From?" Super Gas Pakistan, <http://www.shvpk.com/lpg_where_from.htm> (26 March 2003).

[6] Michael Wang, "Well-to-Wheels Energy and Greenhouse Gas Emissions Impacts of Liquefied Petroleum Gas Vehicles," Prepared for the World LP Gas Association, Revised in November 2002.

[7] U.S. Energy Information Administration, *Alternatives to Traditional Transportation Fuels 2000*, Table 12, "Estimated Consumption of Alternative Transportation Fuels in the United States, by Fuel and Vehicle Weight, 1998, 2000, and 2002," http://www.eia.doe.gov/cneaf/alternate/page/datatables/table12.html.

[8] World LPG Association, ROW = Rest of World

1.2 LPG Properties

In its natural state, LPG changes to liquid under moderate pressure. In vehicle tanks, which are only filled to 80 percent of their volumes to allow for liquid expansion, LPG is stored at about 200 psi at 100°F. The liquid then converts back to a gas upon delivery to the engine, and is combusted as such. All of the properties of LPG described below refer to the fuel in its liquid state.

The two primary constituents of LPG are propane and butane. Propane has a density of 4.22 pounds per gallon and butane has a density of 4.83 pounds per gallon, while gasoline is on the order of 6.0 to 6.5 pounds per gallon. Propane and butane are about 32 percent and 23 percent less dense than conventional gasoline, respectively. At typical storage conditions, propane has an energy content per unit volume of 84,000 Btus per gallon—73 percent of the energy content of gasoline—and butane has an energy content of 94,150 Btus per gallon, or 82 percent that of gasoline. Table 1-1 details this comparison.

Table 1-1. Properties of Conventional Gasoline, Propane, Butane, Diesel, and Compressed Natural Gas (CNG)

	Conventional Gasoline (CG)	Propane	Butane	Diesel	CNG (@3000psi)
Chemical formula	mixture of CxHy between C4 and C12	C_3H_8	C_4H_{10}	mixture of CxHy between C8 and C25	CH_4
Density lbs/gal @60°F	6.0 – 6.5	4.22	4.83	6.7 – 7.4	1.07
Carbon content (% weight)	85-88%	82%	83%	84-87%	75%
Energy Content (Btu/Gal)	115,400	84,000	94,150	129,000	29,000
Energy Content Relative to CG (by volume)	--	75%	82.5%	112%	26%
Fuel Cost (US) per Btu Relative to CG (Average 1999-2001)[9]	--	71%	71%	70%	74%
Vehicle Fuel Efficiency (relative to equivalent CG vehicle)[10]	--	100-105%	100-105%	115-135%	90-100%[11]

[9] U.S. Energy Information Administration, "Alternatives to Traditional Transportation Fuels 2000," Table 12, <http://www.eia.doe.gov/cneaf/alternate/page/datatables/table12.html> (12 May 2003).

[10] Michael Wang "Well-to-Wheels Energy and Greenhouse Gas Emissions Impacts of Liquefied Petroleum Gas Vehicles," Prepared for the World LP Gas Association, Revised in November 2002.

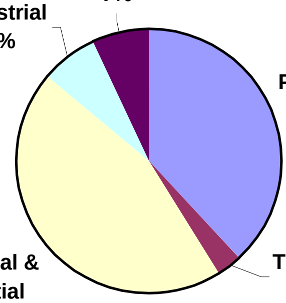
[11] Depending on whether the vehicle is dedicated or bi-fueled (a dedicated vehicle is a vehicle that is able to operate with only fuel system, a bi-fuel vehicles is a vehicle with two fuel systems, but with only one useable at a time).

1.3 LPG Supply and Demand

Over the past ten years, the worldwide growth rate of LPG production has been 3.5 percent per year, while world crude oil production has grown at the rate of just 1.5 percent per year and world natural gas production has grown at the rate of 2.1 percent per year.[12] In most developed countries, LPG is available almost everywhere. In developing countries, LPG is typically available at least in the major population centers if not throughout the entire country.

Worldwide production of LPG in 2001 was about 210 million metric tons. Only about 8 percent of all LPG is used in transportation vehicles, with the other major uses being heating and cooking, agriculture, industrial uses, chemical industry uses, and use in refineries.[13] As shown in Figure 1-2, although LPG is the most widely used of any alternative transportation fuel in the U.S., transportation represented only 3 percent of total U.S. LPG demand in 2000.

Figure 1-2. U.S. LPG Demand by Sector[14]



Many countries encourage the use of LPG as a transportation fuel through tax incentives, with South Korea being perhaps the most extreme example. The price of LPG in South Korea has been regulated to about 22 percent that of gasoline through manipulation of excise taxes, which resulted in LPG use in vehicles growing by nearly 25 percent in 1999 and 2000. This high rate of growth is expected to slow, however, given that the South Korean government plans to increase excise taxes by 2005 so that LPG achieves 65 percent the price of gasoline.[15] In some developing countries, LPG is in high demand because it is also used for home cooking to replace the burning of wood and coal in the home for health reasons.

1.4 LPG Production

LPG is produced from both crude oil and natural gas refining processes, as illustrated in Figure 1-3. In the U.S., 4.11 million barrels of LPG were produced per day in 2000 and an additional 49

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[12] U.S. Energy Information Administration, "LPG/Propylene Supply and Disposition, 1973 – Present." <http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_monthly/current/txt/table_s08_a.txt> 12 May 12, 2003); Table 1.2 "Energy Production by Source 1949-2001", http://www.eia.doe.gov/emeu/aer/txt/ptb0102.html (12 May 2003).

[13] World LP Gas Association, <http://www.worldlpgas.com> (12 May 2003).

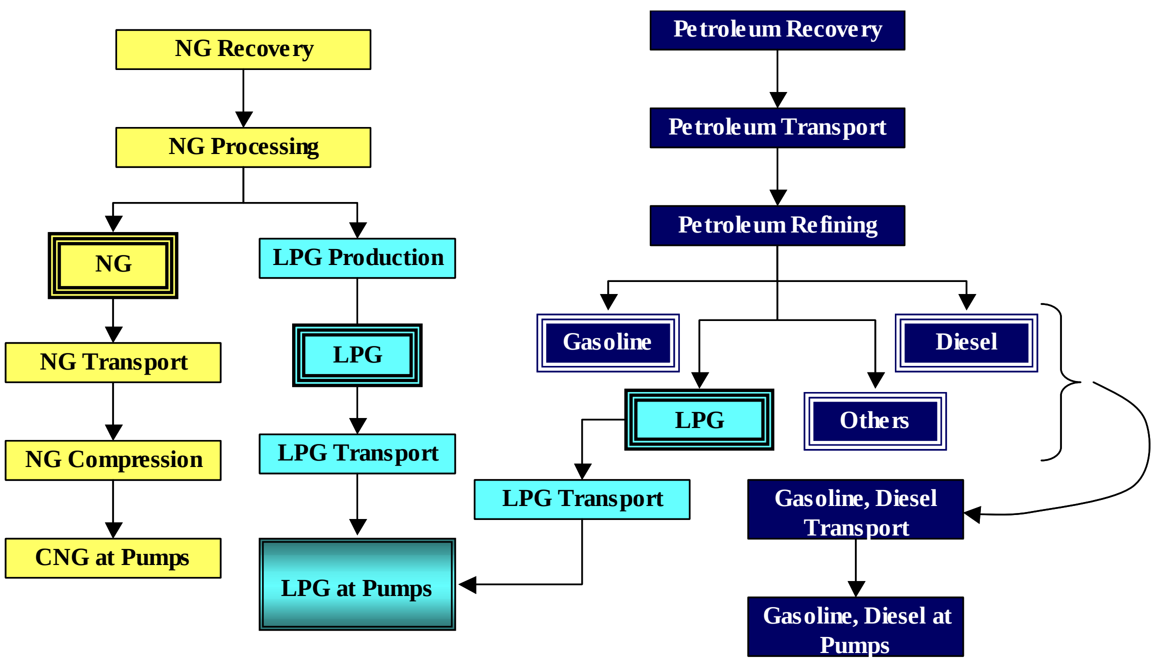
[14] American Petroleum Institute, *2000 Sales of LPG.*

[15] U.S. Energy Information Administration " International Energy Outlook 2002," <http://www.eia.doe.gov> (12 May 2003).

million barrels were imported that year.[16] Since LPG is a by-product of natural gas and petroleum refining, the amount of LPG produced has limited capability to be adjusted when prices and/or demand for LPG fluctuate. Additionally, although imports provide the smallest component of U.S. LPG supply (about 10 percent), they are vital when domestic demand exceeds available domestic supplies. LPG is imported by land via pipeline and rail car from Canada and by sea in tankers from such countries as Algeria, Saudi Arabia, Venezuela, Norway, and the United Kingdom.[17]

In the case of petroleum refining, LPG is produced via the same distillation process as gasoline, with a production efficiency of between 92.5 percent and 94.5 percent; that is, for every 100 Btus of energy produced, 7.5 to 5.5 Btus are consumed in the production process.[18] In the case of LPG produced from natural gas processing, the raw natural gas must be cleaned of its impurities before transmission in pipelines as high purity natural gas (~98 percent methane). The impurities in the raw gas include water, carbon dioxide (CO_2), sulfur compounds, and quantities of natural gas liquids including propane, butane, and natural gasoline, all of which must be removed before transmission. The production of LPG in natural gas processing plants therefore involves the separation of the propane and the butane from the raw natural gas stream, which takes place with an efficiency of 96.5 percent. For every 100 Btus of energy produced, 3.5 Btus are consumed in the production process.[19]

Figure 1-3. Upstream Paths for LPG From Petroleum and Natural Gas Refining



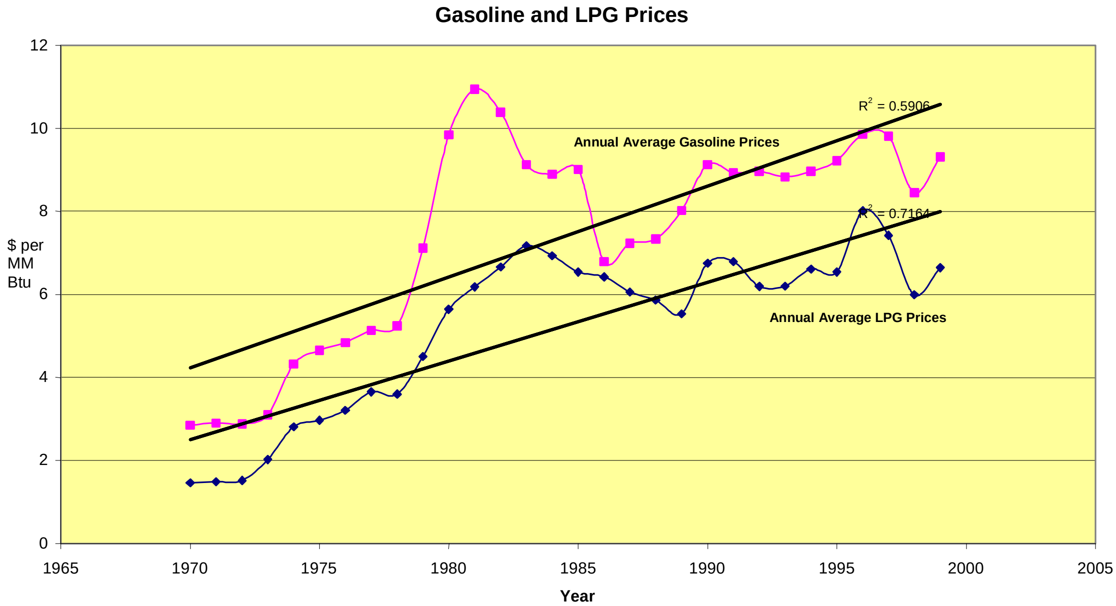
1.5 Fuel Price

The price of LPG is influenced mainly by the cost of crude oil, despite being produced from both crude oil refining and natural gas processing. This is because LPG competes mostly with crude oil-based fuels. Prices for LPG and gasoline tend to fluctuate more or less in step with one

[16] Michael Wang, "Well-to-Wheels Energy and Greenhouse Gas Emissions Impacts of Liquefied Petroleum Gas Vehicles," Prepared for the World LP Gas Association, Revised in November 2002.
[17] Energy Information Administration, "LPG Prices: What Consumers Should Know,". 26 March 2003.
[18] Michael Wang, GREET 1.5—Transportation Fuel Cycle Model, Argonne National Laboratory, Center for Transportation Research.
[19] Ibid.

another as shown in Figure 1-4. Since 1970, annual LPG prices have averaged about 70 percent of gasoline prices, excluding taxes.[20] In the past three years in the U.S., the price of gasoline has outpaced that of LPG, such that the price of LPG has been 65 percent that of gasoline.

Figure 1-4. Annual Average U.S. Gasoline and LPG Prices



[20] U.S. Energy Information Administration, "Consumer Price Estimates for Energy, 1970-1999," Table 3.3, <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec3_7.pdf> (12 May 2003); "LPG Prices: What Consumers Should Know."

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2 LPG Vehicle Technology Options

2.1 Types of Vehicles

LPG can be used in all types of vehicles, but it is better suited to vehicles with spark ignition engines. Passenger cars and light trucks are the most common types of LPG vehicles, but LPG can also be used in medium-duty trucks. LPG motor scooters and LPG three-wheelers are also used in some developing countries. LPG is used to power virtually all the taxis in Japan, using fuel imported from the Middle East in specially made tankers. LPG is very well suited to use in school and shuttle buses because these vehicles use large amounts of fuel and are typically refueled at a central site. LPG is seldom used in heavy-duty vehicles since LPG engines for this application do not exist except for a few conversions of existing heavy-duty vehicle engines.

There are two types of LPG vehicles: dedicated and bi-fuel. Dedicated LPG vehicles are configured to only use LPG. Bi-fuel LPG vehicles (also called dual-fuel vehicles) are configured to use LPG and gasoline. Most bi-fuel LPG vehicles are optimized for gasoline. The engines of dedicated LPG vehicles can be optimized for LPG—through measures such as increased compression ratio and different spark timing—which can result in increased power and efficiency.

LPG vehicles do not have evaporative or running loss emissions and they are capable of producing very low carbon monoxide and hydrocarbon emissions. Emissions of oxides of nitrogen are not significantly different from vehicles using gasoline. LPG is also not very reactive, so it does not contribute significantly to ozone production. In addition, LPG vehicles have very low levels of particulate emissions. LPG vehicles can have relatively high refueling emissions, though this is being addressed by regulations and development of new refueling nozzle and connector technology.

2.2 Conversions and Original Equipment Manufacturers (OEMs)

Most of the existing LPG vehicles in the world are conversions of gasoline vehicles, primarily in bi-fuel configuration. New LPG vehicles are available in the U.S. and Europe.

U.S.

Ford offers bi-fuel pickup and medium-duty trucks. Eleven models of LPG shuttle buses of all sizes are offered by several bus manufacturers. Four medium-duty truck chasses are offered with LPG engines. Freightliner offers a medium-duty truck with the Cummins LPG engine and Omnitrans offers a medium-duty truck chassis using the choice of three models of General Motors LPG engines.

Europe

Volvo offers a bi-fuel LPG engine across almost all its models of passenger cars and wagons. Vauxhall offers bi-fuel versions of its Astra, Zafria, New Vectra, Astravan, and Combo models (passenger cars, vans, and light panel vans). Renault offers an LPG engine in its Kangoo five-passenger vehicle, which comes in several configurations including a light panel van.

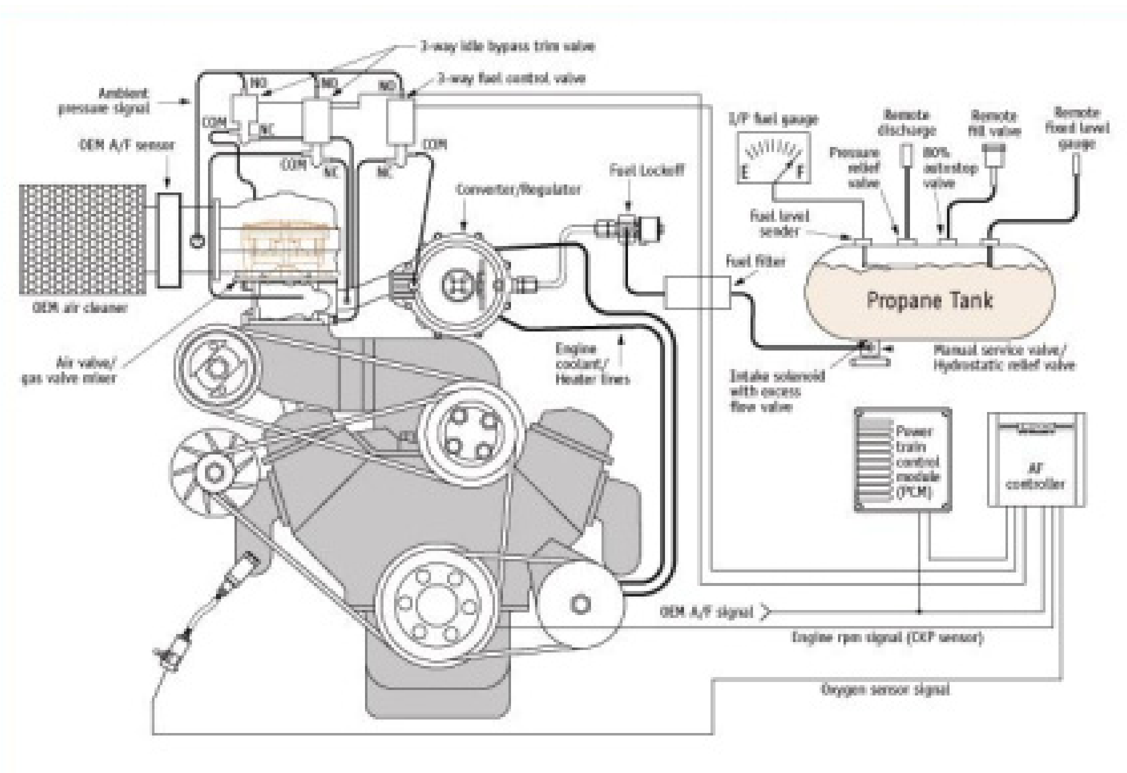
2.3 Fuel System Types

An LPG fuel system must take LPG from the fuel tank and mix it in the correct proportion with air for combustion in the engine. As vehicle fuel systems have evolved, so have LPG fuel systems. The following are descriptions of the three different types of LPG fuel systems.

Gaseous Mixers

In this type of fuel system, liquid LPG is taken from the fuel tank and first vaporized (in the vaporizer) and then mixed with the air entering the engine (the mixer). This type of system is most commonly used in bi-fuel conversions since it introduces the LPG upstream of the gasoline fuel system allowing either fuel system to be used (see Figure 2-1).

Figure 2-1. Example of an LPG Conversion System[21]

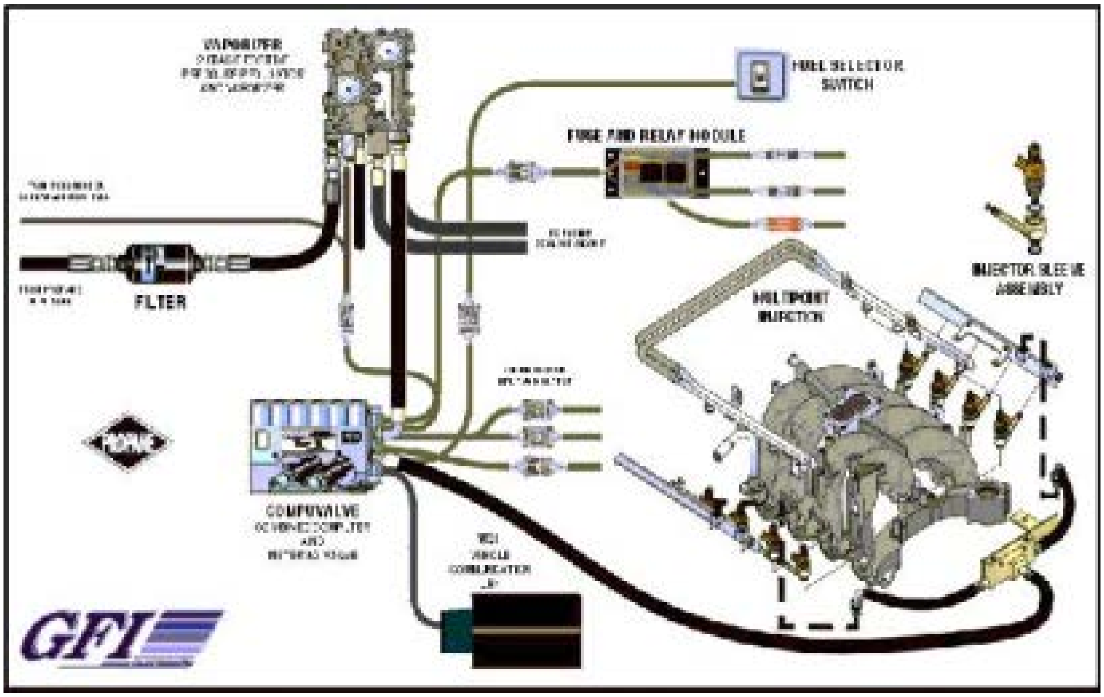


Gaseous Injection

This system is similar to the Gaseous Mixer system except in this case the vaporized LPG is metered into the engine using a single injector or by an injector for each cylinder, also known as multipoint fuel injection. The advantage of this system over the Gaseous Mixer system is control. Electronic control of the LPG injectors results in better engine response, lower emissions, and higher efficiency (see Figure 2-2).

[21] IMPCO Technologies.

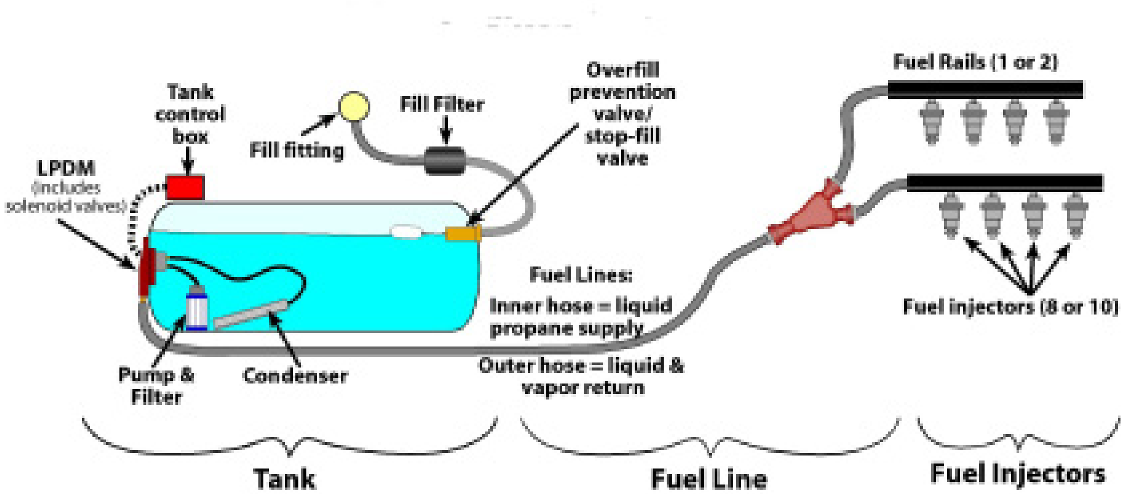
Figure 2-2. Example of a Gaseous Injection System[22]



Liquid Injection

In this system, liquid LPG is injected directly into the engine. These systems take the typical multipoint gasoline fuel injection system and modify it with changed injectors and operating pressure to use liquid LPG directly. Like gaseous multipoint LPG injection, this system results in better engine response, lower emissions, and higher efficiency. However, while the other two types of systems are readily amenable to use as bi-fuel conversion systems, this system is primarily aimed at dedicated LPG vehicles (see Figure 2-3).

Figure 2-3. Example of a Liquid Injection System[23]



[22] TeleflexGFI Control Systems LP.
[23] Bi-Phase Technologies, Inc.

2.4 Vehicle Performance

Most current LPG vehicles have performance and drivability characteristics that are indistinguishable from their gasoline counterparts. Emissions, which are further discussed in Chapter 3, tend to be lower than from gasoline. For example, the current Ford bi-fuel LPG pickup truck has an Ultra Low Emission Vehicle (ULEV) emission rating in the U.S. Evaporative emissions from the gasoline fuel system prevent this vehicle from achieving Inherently Low Emission Vehicle (ILEV) status. If this vehicle were a dedicated LPG vehicle it is likely that it could achieve Super Ultra Low Emission Vehicle (SULEV) emission status since that is the emission rating of the comparable natural gas version of this vehicle (See Appendix A4 for a description of ULEV, ILEV, and SULEV emission ratings in the U.S.) Emissions of LPG engines for medium-duty trucks and buses already easily meet the U.S. Environmental Protection Agency (EPA) 2004 standards, and the technology for achieving the 2007 standards is already in hand.

Appendix A1 compares LPG Vehicles to gasoline-powered vehicles of similar performance in more detail.

2.5 Vehicle Costs

In the U.S., new light-duty LPG vehicles tend to cost $3,500 to $5,000 more than their gasoline counterparts. Conversions of the latest technology vehicles are in the same range. Conversions of older technology vehicles and smaller vehicles in developing countries can cost much less since very simple systems can be used with these vehicles and installation labor is typically lower.

2.6 Refueling Infrastructure

LPG is transported primarily by pipeline and truck to local distributors. Dispensing LPG into vehicles is similar to dispensing gasoline, except that a tight connection is essential to prevent the pressurized LPG from escaping. In most countries where LPG is used as a vehicle fuel, it is dispensed along-side gasoline and diesel fuel in the same refueling stations. LPG is also sold at stand-alone LPG refueling stations.

LPG refueling facilities consist of a bulk storage tank, a transfer pump, and a dispenser for refilling vehicles. U.S. LPG storage tanks must be built to either U.S. Department of Transportation (DOT) regulations for cylinders or American Society of Mechanical Engineering (ASME) pressure vessel codes. Steel is the most common material for LPG tanks, though aluminum is also allowed and is popular for portable LPG tanks. LPG tanks for refueling vehicles can be located above or below ground level.

Dispensers for LPG can be configured like dispensers for gasoline with readouts for gallons dispensed and accumulated total purchase price. The dispenser controls operation of the transfer pump, and emergency shut-down switches should be incorporated.

The National Fire Protection Agency Standard 58 (NFPA 58) is the standard for LPG refueling facilities most widely consulted by building code officials across the U.S. LPG refueling facility fire suppression systems can be dry chemical or water based—the decision about which to use depends on the siting of the facility and on local fire protection codes and regulations. Emergency plans to deal with inadvertent releases of LPG or LPG fires should be worked out with the local fire, police, and emergency response agencies.

LPG refueling facilities for fleet operations can be very simple and easy to establish. Figure 2-4 shows two refueling systems. The left figure is a skid-mounted 1,000 gallon system set up to refuel light-duty vehicles, and the right figure is a more sophisticated system using a 2,000 gallon vertical tank which makes the entire installation very compact. As a general rule of thumb, LPG refueling systems cost in the range of US$2 - US$3 per gallon of storage, with the basis systems at the lower end and the more sophisticated systems at the upper end.[24] Fueling systems to re-fuel fleets can often be financed by the LPG supplier through a surcharge on the fuel price.

Figure 2-4. Left: 1000 Gallon Skid-Mounted LPG Refueling System[25]

Right: 2000 Gallon Vertical Tank LPG Refueling System[26]

[24] Robert Myers, "LPG Vehicle Infrastructure," LPG Vehicle Council, presented at the 1998 SAE Government/Industry Meeting, 20-22April 1998, Washington, D.C.

[25] New York State Energy Research and Development Authority, "Alternative Fuels for Vehicles Fleet Demonstration Program," Final Report 97-4, Volume 3, October 1977.

[26] Richard L. Bechtold, "Alternative Fuels Guidebook," Society of Automotive Engineers, April 1977.

2.7 Example of a LPG Vehicle Project

United States Bakery Company

Between 1985 and 2002, the United States Bakery Company (USBC), with roots in Portland, Oregon, converted its former gasoline-fueled delivery fleet to run on LPG. The conversion was motivated by lower maintenance costs observed for its 15 LPG vehicles compared to its gasoline vehicles. Today, USBC has a fleet of 160 LPG and 40 gasoline light- and medium-duty vehicles, with an average of 100,000 miles of driving for each LPG engine.[27]

The company's LPG vehicles have been performing reliably with overall operating and maintenance costs better than their gasoline counterparts. Fuel costs are responsible for some of the savings, as USBC paid between 10 and 20 cents less per gasoline-equivalent gallon for the LPG compared to gasoline. And because LPG burns cleaner—leaving no lead, varnish, or carbon deposits—the lubricating oil stays cleaner longer.

In addition, the company has experienced significant savings from reduced environmental and liability risks. By converting much of its fleet to LPG, USBC was able to remove 16 of its 19 underground gasoline storage tanks and replace them with aboveground LPG tanks provided by the LPG supplier. The removal of the underground tanks saves the company US$100,000 annually on liability insurance and environmental safeguards associated with these tanks. Meanwhile, the fleet's environmental record has improved. Between 2000 and 2002, the fleet's gasoline vehicles had a 10 percent failure rate against state and federal emission standards while, over the same period, the LPG vehicles had three failures out of more than 400 tests. The fuel economy of the gasoline vehicles has been slightly better—on average, nine miles per gallon for gasoline versus eight miles per gallon for LPG for typical delivery vehicles. However, despite having lower fuel economy, the range of the LPG vehicles is not impacted because the LPG tanks are sufficiently larger than the gasoline tanks to compensate.

USBC cautions that before converting to LPG, engines must be thoroughly inspected, tested, and overhauled to function like new. If a weak, worn-out engine is converted to LPG, vehicle performance will suffer and the potential savings and benefits may not materialize.[28]

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[27] Oregon Office of Energy, "LPG proves the problem free recipe for United States Bakery fleet," 19 March 2003, <http://www.energy.state.or.us/trans/franz.htm> (12 May 2003).

[28] Ibid.

3 GHG Emissions from LPG and Other Alternative Fuel Vehicles

3.1 Overview of GHG Emissions from AFVs

The main GHGs associated with on-road vehicular transportation are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). CO_2 is by far the GHG emitted in largest quantity by the transportation sector because it is the natural result of combustion of carbon-based fuels. Although CH_4 and N_2O are emitted in much smaller quantities than CO_2, their significance is increased due to the fact that CH_4 has 21 times the Global Warming Potential (GWP) of CO_2 over a 100-year time frame, and N_2O has a GWP of 310 over a similar time frame.[29] Box 4-1 describes the Global Warming Potential of GHGs in more detail. Despite the greater GWP of CH_4 and N_2O, carbon dioxide comprises the majority of GHG emissions — between 90 and 96 percent on a "well-to-wheel," or full life cycle basis depending on the type of vehicle and fuel used.

Box. 3-1. Global Warming Potentials (GWP)

GWP is the degree to which a certain GHG will enhance the overall effect of global warming. It is a function of the gas's radiative forcing potential, or how well the gas transmits visible radiation and traps infrared radiation. GWP is expressed in relative terms, with CO_2 as the base, for a given period of time as different gases will have different atmospheric lifetimes. The concept of GWP allows for the comparison of emissions of different GHGs, such as CH_4 and CO_2, using a common unit expressed in terms of tons of CO_2 equivalent (tCO_2e). With a 100-year time horizon, CH_4 has a GWP of 21, meaning that over a 100-year period, the emission of one ton of CH_4 will have the same effect as if 21 tons of CO_2 had been emitted.

Global Warming Potentials of Selected GHGs, 100 Year Time Frame

Greenhouse Gas	Global Warming Potential
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310

GHGs that are emitted as a result of the use of transportation vehicles can be grouped into two general categories: *Upstream* and *Tailpipe* emissions. Together, these comprise the "well-to-wheel" or full life cycle GHG emissions for each unit of fuel consumed or mile driven.

[29] Although the IPCC's Third Assessment Report identifies the GWP of CH_4 and N_2O as 23 and 298 rather than the 21 and 310 found in the Second Assessment Report, the UNFCCC inventory, national communications and the Kyoto Protocol continue to apply the numbers of 21 and 310 since these numbers were used for negotiating the terms of the Kyoto Protocol. The EPA uses 21 and 310 and provides conversions to 23 and 298. The U.S. Energy Information Administration uses 23 and 298 and provides conversions to 21 and 310. In this report we use 21 and 310.

- *Upstream Emissions* are the GHGs emitted during the production, transport, and delivery of the fuel to the vehicle. These emissions take place as a result of fuel combustion in the feedstock production and fuel refining processes, along with the fugitive emissions that take place at each stage of the process. For a complete picture of GHG emissions associated with the use of a vehicle, both tailpipe and upstream emissions should be considered.

- *Tailpipe Emissions* are the GHGs that are produced as a result of the actual operation of the vehicle. In general, tailpipe emissions account for between 75 percent and 85 percent of total emissions.[30] Some methodologies for quantifying GHG emissions from transportation projects account for tailpipe emissions only and, of these, some only account for tailpipe emissions of CO_2.

Origin of Methane (CH_4) Emissions

As natural gas is moved from the wellhead through the transmission pipelines to the refining plant, and then to the distribution networks, there is some leakage from valves, meters, and flanges, which results in the release of CH_4 to the atmosphere called fugitive emissions. The majority of CH_4 emissions are fugitive emissions from equipment leaks at gate stations and distribution pipelines. In addition to fugitive emissions, there are maintenance-related emissions when pressure valves and gathering pipelines are emptied. At the natural gas processing facility, heavy hydrocarbons and contaminants are removed from the gas, causing additional fugitive and maintenance-related emissions. Furthermore, CH_4 emissions may take place as a result of system upsets or accidents, during which sudden increases in pressure require the release of gas as a safety measure, or when a portion of the system ruptures, releasing large volumes of gas. Currently, the U.S. natural gas system is operating below capacity, reducing the frequency of such events.[31]

CH_4 and other gases are also produced and released when fuel is not fully combusted in the vehicle engine. This is especially true for CNG, and to a lesser extent for LPG. These so-called “mobile source” CH_4 emissions are affected by a number of factors, including the amount of unburned hydrocarbons passing through the engine, the engine type and maintenance conditions, and any post-combustion control of hydrocarbon emissions such as the use of catalytic converters. Emissions of CH_4 are highest when the air-fuel mixture is "rich," that is, the amount of oxygen present is insufficient for complete combustion. This condition occurs most frequently during acceleration and when climbing steep hills.[32]

Origin of Nitrous Oxide (N_2O) Emissions

N_2O is produced in motor vehicle engines through reactions with atmospheric nitrogen, similar to those reactions producing nitrogen oxide (NO) and nitrogen dioxide (NO_2). Research indicates that catalytic converters, installed to control the emissions of carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), and nitrogen oxides (NO_X), actually promote the formation of N_2O. N_2O is produced during the reaction of NO and ammonia (NH_3) over the platinum in the catalytic converter. As the share of the U.S. motor vehicle fleet equipped with catalytic converters has increased over the years, so have emissions of nitrous oxide from this

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[30] These figures are based on Argonne National Laboratory’s GREET Model, using default input assumptions such as process fuels used, the energy efficiency of the various refining and operation processes, etc. For more information on the GREET model, see: Michael Wang,. GREET 1.5—Transportation Fuel Cycle Model. Argonne National Laboratory, Center for Transportation Research, <http://www.transportation.anl.gov/greet> (12 May 2003).
[31] U.S. Energy Information Administration, <http://www.eia.doe.gov/oiaf/1605/87-92rpt/chap3.html#Transportation> (12 May 2003).
[32] U.S. Energy Information Administration <http://www.eia.doe.gov/oiaf/1605/87-92rpt/chap3.html#Transportation> (12 May 2003).

source.[33] In calculating GHG emissions from those vehicles without catalytic converters, which are common in many developing countries, vehicular N_2O emissions can be assumed to be zero.

Refueling Connections and Their Impact on Evaporative Emissions

The release of LPG during vehicle refueling presents important environmental and safety concerns. LPG refueling emissions are a concern because LPG must be pumped into the vehicle tank as a pressurized liquid. When the tank is full, the pressure in the refueling line is at or above the vehicle tank pressure. During refueling, the pressure in the refueling line is typically between 80 psi (pounds per square inch) and 125 psi to achieve tank refill in times similar to refueling conventional fuel vehicles. When the refueling nozzle is released, the LPG in the “dead volume”—the volume between the check valve or shut-off valve of the refueling nozzle and the check valve in the tank refueling line—is released to the atmosphere. The “Acme Thread” refueling connections used in North America and several European countries allow different manufacturer refueling nozzles to mate with different manufacturer refueling receptacles with a resulting wide range of dead space volumes (see Figure 3-1).

Figure 3-1. Left: Acme Thread LPG Refueling Nozzle; Right: EU LPG Refueling Nozzle[34]

Worst case refueling nozzles combined with worst case refueling receptacles can result in the release of up to 80cc (approximately 40 grams) of LPG per refueling.[35] Besides being an emission concern, the release of LPG from these refueling connections causes two safety hazards: first, the rapidly vaporizing LPG can cause frostbite if it contacts unprotected skin, and second, the released plume of LPG vapor represents a fire hazard.

In the U.S., regulations have been passed limiting the refueling emissions from LPG vehicles to 0.15 grams (0.30cc) of LPG per gallon dispensed.[36] In Europe, the Committee for Standardization

[33] U.S. Energy Information Administration, <http://www.eia.doe.gov/oiaf/1605/87-92rpt/chap4.html> (12 May 2003).
[34] Brian J. Birch, Southwest Research Institute, and Steve Jaeger, Texas Railroad Commission, "LPG Refueling Technology," SAE Paper 2002-01-2739 presented at the SAE Powertrain & Fluid Systems Conference & Exposition, San Diego, CA, 21-24 October 2002.
[35] Ibid.
[36] Code of Federal Regulations (CFR) 40, Section 86.1811, <http://www.access.gpo.gov/nara/cfr/> (12 May 2003).

started work on the "Light Vehicle Euro Filling System" in 1998 for LPG vehicles. Their work has resulted in a new design of LPG vehicle refueling system that is easy to connect and disconnect, has a flow rate of 16 gallons (60 liters) per minute, and less than 1 cc LPG release upon disconnect (see Figure 3-1). The EU plans to make the new LPG refueling connection system mandatory on all new LPG vehicles starting in 2005.

The design of LPG refueling connectors and receptacles for use with heavy-duty vehicles differs in that it does not rely on refueling line pressure to open the valves to allow refueling. For this reason and due to careful design to minimize dead volume, the heavy-duty vehicle refueling nozzle has very low per gallon release of LPG upon disconnect and does not present environmental or safety concerns.

Another source of refueling emissions from LPG vehicles is the "spit valve," appropriately named to describe the way it works to assure that LPG tanks are not overfilled. Since LPG tanks are sealed to the atmosphere, they are vulnerable to catastrophic failure should they be filled near capacity and then undergo a rise in temperature. To prevent this from happening, LPG tanks are required by regulation to be filled to only 80 percent of their total volume, leaving sufficient space for expansion under normal circumstances. LPG tanks also have a safety relief valve that opens when the pressure inside the tank exceeds 312 psi to prevent the tank from bursting when subjected to a fire. The most commonly used valve to limit refueling to 80 percent is the spit valve, which is simply a small diameter opening corresponding to the 80 percent fill level of the tank. The spit valve is opened when refueling is started and releases LPG vapor during refueling and LPG liquid when the 80 percent fill point is reached. The release of liquid LPG is immediately evident since the rapidly vaporizing LPG causes condensation of water vapor in the air resulting in a white fog. LPG tanks with spit valves will not meet the U.S. regulations for refueling emissions. A few mechanical fill limiting systems have been developed, but they tend to be unreliable over time as contaminants are deposited in them. The most promising replacement for the spit valve are capacitance-type fuel level sensors that can be used to automatically limit refueling to the 80 percent point, and provide a signal for the level of fuel in the tank for dashboard display.

3.2 GHG Emissions per Vehicle Type

In this section of the report, we present GHG emissions data for six passenger vehicle fuel types: Conventional Gasoline, Reformulated Gasoline, Diesel, Compressed Natural Gas (CNG), and both natural gas- and crude oil-derived LPG. Table 3-1 presents the share of GHG emissions by vehicle fuel type, GHG and stage (tailpipe or upstream). These differences are illustrated in Figure 3-2. The data in these figures are calculated using the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model,[37] developed by Michael Wang at the Argonne National Laboratory.[38]

In the GREET model, a "well-to-wheel" (WTW) approach is employed in order to account for those emissions resulting from all stages of fuel production and use for light-duty vehicles, including feedstock recovery, transportation, and storage; fuel refining, transportation, and storage; combustion of the fuel in the vehicle; and the physical leakage that occurs at each stage. These are grouped into two large groups in the well-to-wheel analysis: well-to-pump (upstream), and pump-to-wheel (tailpipe). The former consists of all stages that contribute to the production and delivery of the fuel to the end user at the pump, and the latter consists of use of the fuel to power the vehicle.

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[37] The GREET model is useful for breaking out GHG emissions by gas and stage, but its inclusion here is not a *de facto* recommendation of its use for developing emission factors.
[38] Michael Wang, GREET 1.5—Transportation Fuel Cycle Model, Argonne National Laboratory, Center for Transportation Research, <http://www.transportation.anl.gov/greet/> (12 May 2003).

The "Total" rows in Table 3-1 are the total GHG emissions for the given stage on a CO_2e basis. For example, the upstream GHG emissions for a conventional gasoline vehicle account for 22 percent of total emissions, while the tailpipe emissions account for 78 percent. Similarly, the "WTW" column is the well-to-wheel contribution of each gas to total GHG emissions. Again, using the conventional gasoline vehicle as an example, CO_2 emissions represent 95.5 percent of total GHG emissions on a CO_2e basis, N_2O represents 1.8 percent and CH_4 represents 2.7 percent.

All the data used in the GREET model are based on current vehicle models and fuel production processes in the U.S. As a result, the numbers presented in the tables may vary for other countries.

The output of the GREET model are per-mile emission factors for a variety of light-duty vehicle models, which can be modified according to the vehicle and geographic specifics of a given project within the U.S. For projects outside the U.S., additional information on the upstream fuel processes in the specific country would have to be input into the model for an accurate estimate of emissions. Note that the emissions from the production of LPG from petroleum and natural gas are listed separately, due to the fact that these are based on independent production processes with different energy requirements, combustion facilities, and fugitive leakage characteristics.

Table 3-1. Shares of GHG Emissions by GHG and Stage for Various Vehicle Types

Conventional Gasoline Vehicle

	Upstream	Tailpipe	WTW
CH4	2.4%	0.3%	2.7%
N2O	0.1%	1.7%	1.8%
CO2	19.5%	76.0%	95.5%
Total	22.0%	78.0%	

Reformulated Gasoline Vehicle

	Upstream	Tailpipe	WTW
CH4	2.9%	0.3%	3.2%
N2O	0.1%	1.7%	1.8%
CO2	20.4%	74.6%	95.0%
Total	23.4%	76.6%	

Diesel Vehicle

	Upstream	Tailpipe	WTW
CH4	2.2%	0.1%	2.3%
N2O	0.1%	1.3%	1.4%
CO2	15.0%	81.3%	96.3%
Total	17.3%	82.7%	

Dedicated CNG Vehicle

	Upstream	Tailpipe	WTW
CH4	5.4%	3.8%	9.2%
N2O	0.1%	1.5%	1.6%
CO2	18.2%	71.0%	89.2%
Total	23.7%	76.3%	

Natural Gas-Derived LPG Vehicle

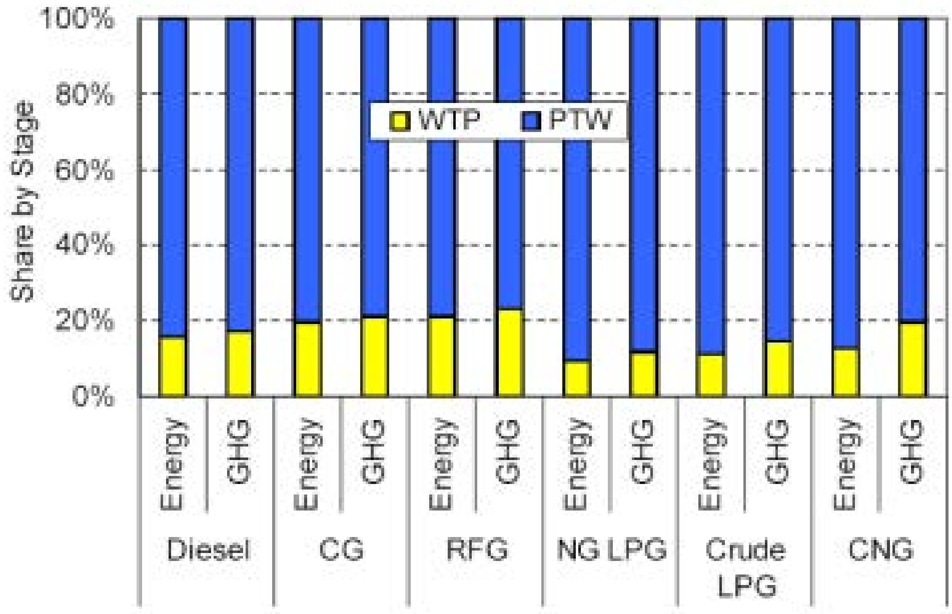
	Upstream	Tailpipe	WTW
CH4	2.7%	0.5%	3.2%
N2O	0.1%	2.0%	2.1%
CO2	11.6%	83.1%	94.7%
Total	14.4%	85.6%	

Crude-Derived LPG Vehicle

	Upstream	Tailpipe	WTW
CH4	2.4%	0.5%	2.9%
N2O	0.1%	1.9%	2.0%
CO2	13.3%	81.8%	95.1%
Total	15.8%	84.2%	

CNG = Compressed Natural Gas

Figure 3-2. Share of Total GHG Emissions by Stage (Upstream Versus Tailpipe)[39]



3.3 GHG Emission Factors

In order to calculate GHG emissions and emission reductions resulting from the use of alternative fuel vehicles, a fleet owner or project manager can use data that are readily available—usually in the form of fuel purchase records and odometer readings—along with appropriate emission factors. The emission factor specifies the quantity of GHGs produced and emitted as a result of the consumption of fuel or miles driven by the vehicles in question. The emission factors presented below derive from the International Panel on Climate Change (IPCC) mobile source emission factors.[40] To check for agreement, we also present emission factors derived from the Argonne National Laboratory GREET model, but since the IPCC factors are more widely recognized internationally, these should be used as the default whenever there is a discrepancy between the two.

For the purpose of estimating GHG emissions, emission factors based on fuel use—expressed in terms of CO_2e per Btu of fuel consumed—are likely to be used more often than emission factors based on CO_2e per mile driven. There are two reasons for this. First, a per-fuel consumption methodology is more accurate because it is not a function of the vehicle fuel economy, whereas a per-mile-traveled emission factor will require fuel economy as an input in the calculation. Since the fuel economy may change over time for a given vehicle and will be different for different vehicle types, an average fuel economy figure will cause some inaccuracy in the calculation. Second, and most importantly, project developers and fleet owners are more likely to keep fuel purchase records as opposed to odometer records of miles driven, and thus a per-fuel consumption methodology will have a greater utility.

[39] Michael Wang, "Well-to-Wheels Energy and Greenhouse Gas Emissions Impacts of Liquefied Petroleum Gas Vehicles," Prepared for the World LP Gas Association, Revised in November 2002. WTP = Well to Pump (Upstream); PTW = Pump to Wheel (Tailpipe); CG = Conventional Gasoline; and RFG = Reformulated Gasoline.

[40] *IPCC Guidelines for National GHG Inventories: Reference Manual, 1996*. <http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm> (12 May 2003).

In the following subsections we provide an overview of some of the most relevant emission factors for quantifying GHG emissions from vehicle projects. These emission factors are organized into two major groupings based on whether they address tailpipe or full fuel cycle emissions. In addition, separate emission factors are provided for examining CO_2 emissions only and for addressing all three relevant GHGs: CO_2, CH_4, and N_2O.

3.3.1 Tailpipe CO_2 Emission Factors

Because of the large share of GHG emissions coming from CO_2 and the simplicity involved with calculating tailpipe CO_2 emissions only and leaving out other GHGs and upstream emissions, many existing GHG accounting systems and projects have accounted for tailpipe CO_2 emissions only. In addition, this type of analysis is often used for illustrating differences in GHG emissions between different vehicle fuel types, assuming the change in all upstream emissions and tailpipe CH_4, and N_2O components are minimal. This method may be preferable in that it requires the least amount of data collection and modeling. However, it is less accurate as it does not address emissions throughout the entire fuel cycle. In the following we describe tailpipe CO_2 emission factors derived by the GREET model and the IPCC guidelines for mobile sources.

Tailpipe CO_2 Emission Factors—IPCC

The CO_2 tailpipe emission factors from the IPCC Guidelines for National GHG Inventories, Reference Manual, 1996 are presented in Table 3-2. Emission factors are listed in terms of grams of CO_2 per MMBtu of fuel, and grams of CO_2 per kg of fuel.

Table 3-2. IPCC Tailpipe CO_2 Emission Factors

	CO2 Emission Factors		
Vehicle Type	grams CO2/MMBtu	grams CO2/kg fuel	Reduction from CG
Conventional Gasoline (CG)	76,061	3,172	0%
Reformulated Gasoline	76,061	3,172	0%
Diesel	76,061	3,172	0%
CNG	59,183	2,750	22%
Crude-Derived LPG	66,568	3,000	12%
NG-Derived LPG	66,568	3,000	12%

Tailpipe CO_2 Emission Factors—GREET

Using the GREET model, the emission factors listed in Table 3-3 were calculated for tailpipe CO_2 emissions.

Table 3-3. GREET Tailpipe CO_2 Emission Factors

	CO2 Emission Factors		
Vehicle Type	grams CO2/MMBtu	grams CO2/kg fuel	Reduction from CG
Conventional Gasoline (CG)	75,701	3,238	0%
Reformulated Gasoline	75,671	3,159	0%
Diesel	80,423	3,190	-6%
CNG	59,427	951	21%
Crude-Derived LPG	71,516	3,004	6%
NG-Derived LPG	71,516	3,004	6%

Since the GREET model calculates emission factors on a per-mile basis, these factors were converted to the desired per-MMBtu basis, and then to the per-kg of fuel basis. This was done by calculating the emission factors for a range of vehicle fuel economies from 20 MPG to 35 MPG, and averaging the results. Although they represent an average, the variation from one fuel economy to another is less than 0.005 percent per mile per gasoline equivalent (MPG-E) for all vehicle types, except CNG. For CNG the variation was slightly higher, but still only 0.031 percent per MPG-E. Thus, the figures in Table 3-3 should be considered accurate over a wide range of vehicle fuel economies.

As Table 3-4 illustrates, the GREET and IPCC figures are in close agreement. However, the IPCC emission factors are about 7 percent lower for LPG fuels and 5 percent lower for Diesel. This is attributable to the different input assumptions in terms of fuel energy content and fuel density used by GREET. As mentioned previously, project developers may wish to use the IPCC factors as a default, since these are more widely recognized.

Table 3-4. Comparison Between GREET and IPCC Tailpipe CO_2 Emission Factors

	GREET	IPCC	
Vehicle Type	CO2 Emission Factors grams CO2/MMBtu	CO2 Emission Factors grams CO2/MMBtu	Difference
Conventional Gasoline (CG)	75,701	76,061	0.48%
Reformulated Gasoline	75,671	76,061	0.51%
Diesel	80,423	76,061	-5.42%
CNG	59,427	59,183	-0.41%
Crude-Derived LPG	71,516	66,568	-6.92%
NG-Derived LPG	71,516	66,568	-6.92%

3.3.2 Tailpipe GHG Emission Factors

Including all transportation-relevant GHGs (CO_2, CH_4, and N_2O) will add a degree of complexity to the quantification of emissions and emission reductions, but it will increase the overall accuracy. Emission factors can be generated through independent testing of the vehicles in question and verified via independent auditing, or default emission factors can be used. Note that these emission factors are on a per-energy and per-kg fuel consumption basis, such that the calculation is based on fuel consumption only. However, the vehicle technology now comes into play, as CH_4 and N_2O emissions will depend on the level of tailpipe pollution control. Finally, as was the case with CO_2 tailpipe-only emission factors, the IPCC factors are to be used as the primary default and the GREET factors are to be used to check for agreement.

Tailpipe GHG Emission Factors—IPCC

The IPCC lists a series of emission factors for GHGs and other pollutants, broken down by vehicle type (e.g.: gasoline-fueled passenger car, diesel-fueled light-duty truck, etc.), level of pollution control (i.e.: catalyst type), the age of the vehicle, and season, for both U.S. and European vehicles.[41] Table 3-5 and Table 3-6 present the subset of these emission factors for CH_4, N_2O, and CO_2 that corresponds to the seasonal average for passenger cars fueled by gasoline, diesel, natural gas, and LPG, broken down by type of pollution control. The values in the table are in terms of CO_2e, which were calculated using the global warming potential of each gas. The “Total” column on the right side of the tables is the sum of each row. Table 3-5 lists the emission factors in terms of grams of CO_2 per MMBtu of fuel consumed and Table 3-6 lists the same emissions factors in terms of grams of CO_2 per kg of fuel consumed.

The IPCC also lists emission factors for European vehicles and driving conditions, and project developers may wish to consult the IPCC guidelines for regional-specific data as necessary. Also,

[41] *IPCC Guidelines for National GHG Inventories: Reference Manual, 1996,* page 1.65. <http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm> (12 May 2003).

for light-duty truck and heavy-duty vehicle emission factors, or for NO_X, NMVOC, and CO emission factors, one should refer to the original IPCC document.[42]

The definitions of the IPCC pollution control classes used in Table 3-5 and Table 3-6 are as follows, taken directly from the IPCC guidelines:[43]

- Light-duty gasoline passenger cars are those vehicles with rated gross weight less than 8,500 lb (3,855 kg) designed primarily to carry 12 or fewer passengers.

- The six levels of gasoline-vehicle control technology are:

  - UNC: Uncontrolled (still typical of most vehicles around the world);

  - NCC: Non-catalyst emission controls - including modifications to ignition timing and air-fuel ratio to reduce emissions, exhaust gas re-circulation (EGR), and air injection into the exhaust manifold;

  - OCC: Oxidation catalyst systems normally including many of the same techniques as an ETW catalyst, plus a two-way catalytic converter to oxidize hydrocarbons and CO;

  - ETW: Early three-way catalyst results representative of vehicles sold in the United States in the early to mid-1980s.

  - ADV: Advanced three-way catalyst values based on current US technology vehicles, using electronic fuel injection under computer control; and

  - LEV: Low Emission Vehicles, which are expected to include sequential multi-port fuel injection with adaptive learning, more sophisticated computer diagnostics and heated catalysts with secondary air injection.

- The IPCC's three levels of diesel passenger vehicle emission control technology are:

  - UNC: Uncontrolled;

  - MOD: Moderate emissions control (achieved by changes in injection timing and combustion system design); and

  - ADV: Advanced emissions control utilizing modern electronic control of the fuel injection system, and exhaust gas re-circulation.

- The estimates for the natural gas- and LPG-fueled passenger cars are based on a gasoline-type engine, converted to use natural gas or LPG. For the uncontrolled vehicles, no changes in the engine are assumed beyond the fitting of a natural gas mixer and modified spark timing such that the efficiency would be the same. For the vehicles with advanced control, a higher compression ratio is assumed to give 15 percent better fuel efficiency. The two levels of natural gas and LPG passenger vehicle emission control technologies are:

  - UNC: uncontrolled, typical of a simple natural gas or LPG conversion, without catalytic converter or optimization for emissions;

  - ADV: advanced control, reflecting an engine and catalytic converter factory-produced and optimized for natural gas or LPG.

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[42] Ibid.
[43] Ibid.

Table 3-5. IPCC Tailpipe Emission Factors for CH_4, N_2O, and CO_2 (grams CO_2e/MMBtu)

US Gasoline Passenger Cars	CH4	N2O	CO2	*Total*
LEV	166	3,273	76,061	*79,501*
TWC	166	14,076	76,061	*90,303*
ETW	211	13,421	76,061	*89,693*
OCC	277	4,583	76,061	*80,921*
NCC	355	982	76,061	*77,398*
UNC	432	982	76,061	*77,475*
US Diesel Passenger Cars	**CH4**	**N2O**	**CO2**	***Total***
ADV	22	655	76,061	*76,738*
MOD	44	982	76,061	*77,087*
UNC	67	982	76,061	*77,109*
US NG Passenger Cars	**CH4**	**N2O**	**CO2**	***Total***
ADV	6,431	N/A	59,183	*65,614*
UNC	13,970	N/A	59,183	*73,154*
US LPG Passenger Cars	**CH4**	**N2O**	**CO2**	***Total***
ADV	222	N/A	66,568	*66,790*
UNC	665	N/A	66,568	*67,233*

Table 3-6. IPCC Tailpipe Emission Factors for CH_4, N_2O, and CO_2 (grams CO_2e/kg fuel)

US Gasoline Passenger Cars	CH4	N2O	CO2	*Total*
LEV	7	140	3,172	*3,319*
TWC	7	587	3,172	*3,765*
ETW	9	561	3,172	*3,742*
OCC	12	193	3,172	*3,377*
NCC	15	39	3,172	*3,225*
UNC	18	40	3,172	*3,230*
US Diesel Passenger Cars	**CH4**	**N2O**	**CO2**	***Total***
ADV	1	28	3,172	*3,201*
MOD	2	40	3,172	*3,214*
UNC	3	43	3,172	*3,218*
US NG Passenger Cars	**CH4**	**N2O**	**CO2**	***Total***
ADV	305	N/A	2,750	*3,055*
UNC	664	N/A	2,750	*3,414*
US LPG Passenger Cars	**CH4**	**N2O**	**CO2**	***Total***
ADV	13	N/A	3,000	*3,013*
UNC	32	N/A	3,000	*3,032*

Tailpipe GHG Emission Factors—GREET

Using the GREET model, the following emission factors were calculated for tailpipe GHG emissions per MMBtu of fuel and per kg of fuel consumed. These are illustrated in Table 3-7 and Table 3-8. The only adjustments made for different vehicle technologies is that for vehicles without catalytic converters, the N_2O emissions are assumed to be zero.

Table 3-7. GREET Tailpipe GHG Emission Factors for Vehicles with Catalytic Converters (grams CO_2e)

	GHG Emission Factors (CO2e)		
Vehicle Type	**grams CO2/MMBtu**	**grams CO2/kg fuel**	**Reduction from CG**
Conventional Gasoline (CG)	78,187	3,345	0%
Reformulated Gasoline	78,124	3,261	0%
Diesel	82,091	3,256	-5%
CNG	64,871	1,038	17%
Crude-Derived LPG	74,128	3,113	5%
NG-Derived LPG	74,128	3,113	5%

Table 3-8. GREET Tailpipe GHG Emission Factors for Vehicles without Catalytic Converters (grams CO_2e)

	GHG Emission Factors (CO2e)		
Vehicle Type	**grams CO2e/MMBtu**	**grams CO2e/kg fuel**	**Reduction from CG**
Conventional Gasoline (CG)	76,121	3,256	0%
Reformulated Gasoline	76,058	3,175	0%
Diesel	80,497	3,193	-6%
CNG	63,333	1,013	17%
Crude-Derived LPG	72,062	3,027	5%
NG-Derived LPG	72,062	3,027	5%

As mentioned previously, the GREET model calculates emission factors on a per-mile basis and some conversions were thus required to convert to a per-MMBtu and per-kg basis, which was done by calculating the emission factors for a range of vehicle fuel economies, from 20 MPG-E to 35 MPG-E, and averaging the results. The variation between fuel economies is higher in the case where all GHG emissions are accounted for (as opposed to CO_2 only), but it is still less than 0.125 percent per MPG-E for all vehicle types except CNG. For CNG the variation was higher, at 0.276 percent per MPG-E. Thus, the factors in Table 3-7 and Table 3-8 should be considered accurate over a wide range of vehicle fuel economies for light duty vehicles. Although based on U.S. conditions, these emission factors can be used for cases outside the U.S. as well, although it should be recognized that the overall accuracy might be diminished.

3.3.3 Full Fuel Cycle GHG Emission Factors

Accounting for upstream emissions is much more difficult than accounting for tailpipe emissions, as the upstream energy use and fugitive emissions may vary significantly from one facility and country to another. Furthermore, the exact refinery or fuel source will likely not be known by the fleet owner using the fuel. Therefore, if a project developer or offset program wishes to account for upstream emissions, the authors recommend one of the following three options:

1) Use a fuel-independent correction factor that converts tailpipe CO_2 or tailpipe GHG emissions to total tailpipe and upstream GHG emissions. This method acknowledges that the differences in upstream GHG emissions between different fuels are too difficult to ascertain, and that some default factors will have to be used. Based on the GREET model outputs presented in Figure 3-1, we recommend a tailpipe CO_2-to-total GHG correction factor of 22 percent, and a tailpipe GHG-to-total GHG correction factor of 19 percent. For example, if the tailpipe GHG emission factor for a given vehicle is 80,000 grams CO_2e/MMBtu of fuel, then the corrected total GHG emissions (upstream and tailpipe) would be:

80,000 grams CO_2e/MMBtu x 1.19 = 95,200 grams CO_2e/MMBtu

2) Use a fuel-specific correction factor that converts tailpipe CO_2 or tailpipe GHG emissions to total GHG emissions. This method acknowledges and takes into account the differences in upstream GHG emissions between different fuels. In the U.S. these differences are well known, and a fuel-specific correction factor could be used with a good degree of confidence. We recommend the correction factors illustrated in Table 3-9, which are taken directly from the GREET model using default input parameters.[44] The correction factors should be applied as illustrated in the previous paragraph.

Table 3-9. Fuel-Specific Upstream GHG Correction Factors

Vehicle Type	Tailpipe CO_2-to-Total GHG Correction Factor	Tailpipe GHG-to-Total GHG Correction Factor
Conventional Gasoline	24%	22%
Reformulated Gasoline	25%	23%
Diesel	19%	17%
CNG	29%	24%
Natural Gas-Derived LPG	17%	14%
Crude-Derived LPG	18%	16%

3) Gather the data necessary to accurately use a model such as GREET, which can calculate upstream emissions. This is a complicated process and beyond the scope of this report. However, it should be noted that GREET is designed to yield emission factors on a per-mile basis, as opposed to a per-fuel consumption basis. This means that the project manager or fleet owner would have to have access to accurate fuel economy data to calculate the resulting emissions.

3.4 Illustration of Potential GHG Emission Reductions

Although per-mile emission factors may be impractical for a fleet/project manager with access to fuel purchase records, they are useful to illustrate the potential for calculating GHG emissions resulting from a given project.

Figure 3-3, Figure 3-4 and Figure 3-5 illustrate the results from the GREET model using the default input parameters. These default parameters include a gasoline vehicle fuel economy of 22.4 MPG, a diesel fuel economy of 30.24 MPG-E, a CNG fuel economy of 20.83 MPG-E, and a LPG fuel economy of 22.4 MPG-E. The figures include error bars which correspond to a range of possible values derived from statistical probabilities of the input assumptions. For more on the probability assumptions and statistical modeling, please see “Well-to-Wheels Energy and Greenhouse Gas Emissions Impacts of Liquefied Petroleum Gas Vehicles,” by Michael Wang (prepared for the World LP Gas Association, November 2002).

[44] The GREET default input parameters cover a range of upstream process efficiencies and fuel types.

Figure 3-3. GREET Upstream and Tailpipe Energy Use (Btu/mile)

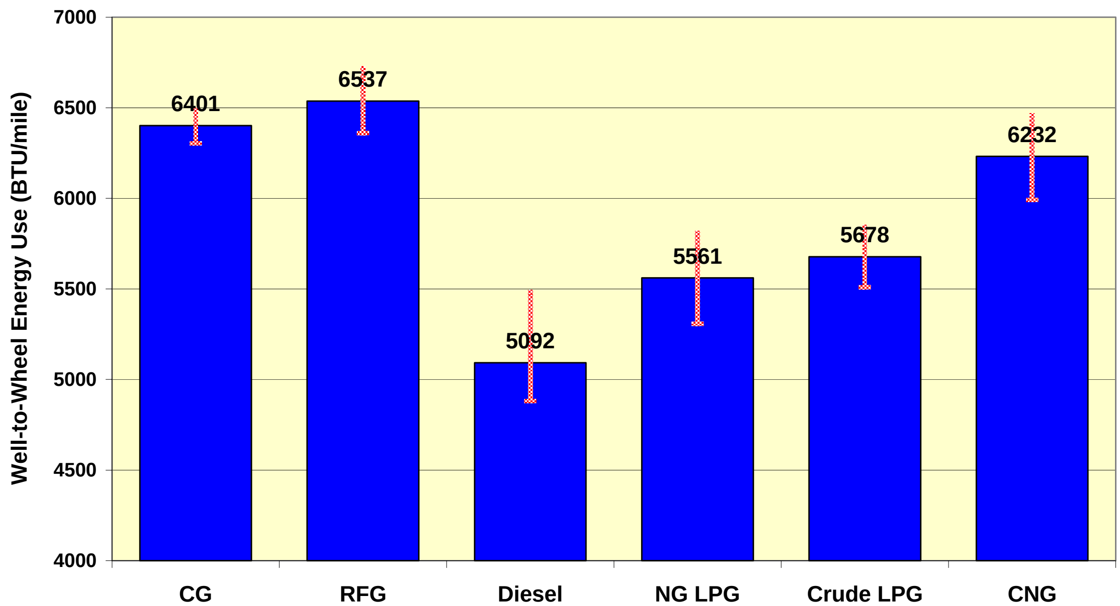
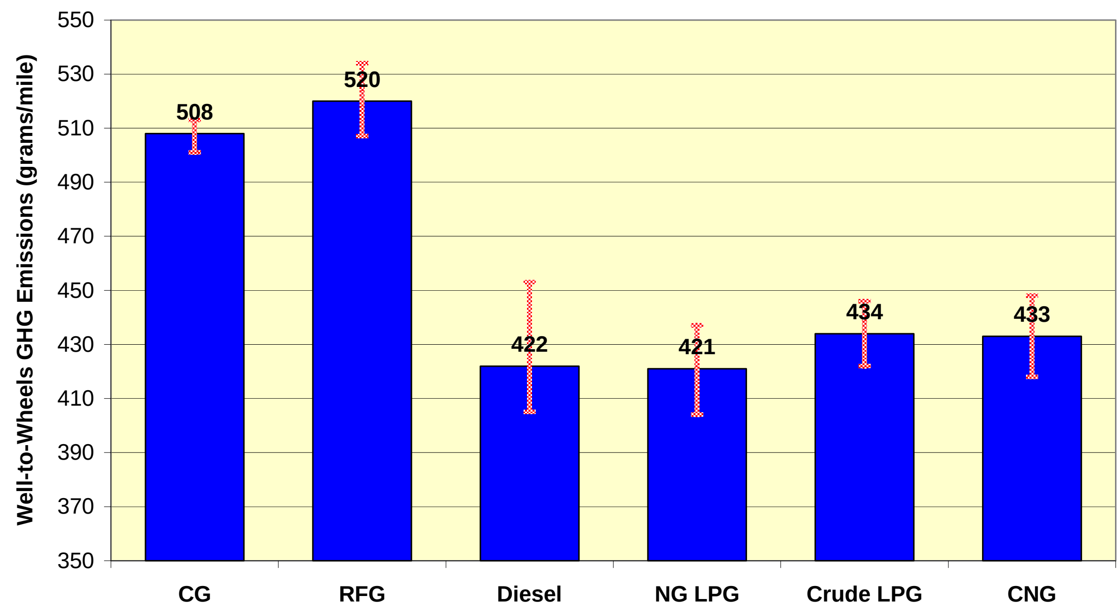
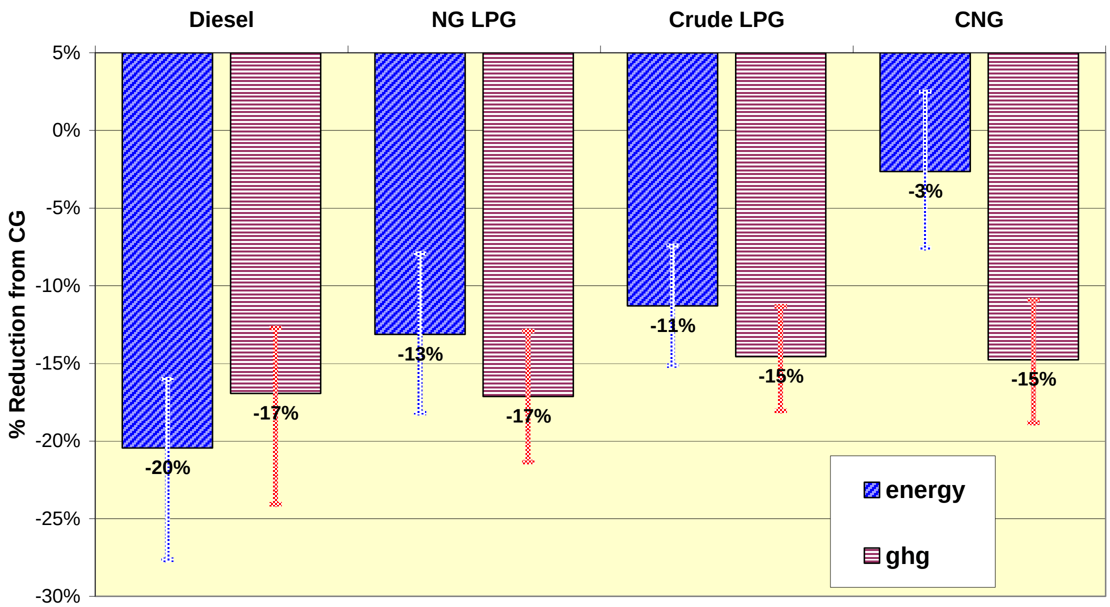


Figure 3-4. GREET Upstream and Tailpipe GHG Emissions (grams CO_2e/mile)



As Figure 3-5 illustrates, use of diesel vehicles reduces energy use by 17-27 percent and GHG emissions by 14-23 percent over conventional gasoline (CG). Natural gas-derived LPG vehicles reduce energy use by 9-17 percent and GHG emissions by 14-20 percent, and crude-derived LPG vehicles reduce energy use by 9-14 percent and GHG emissions by 12-17 percent. CNG vehicles reduce energy use by up to 6 percent and GHG emissions by 12-18 percent over CG. GHG emissions and energy use are not proportional because (a) the different fuels have different carbon-to-hydrogen ratios, and (b) gas leakage contributes to GHG emissions, but not to energy use.

Figure 3-5. Percent Reductions in Energy Use and GHG Emissions Relative to an Equivalent Gasoline Vehicle Fueled with Conventional Gasoline



3.5 Using Emission Factors to Calculate GHG Reductions

Once the appropriate emission factor has been selected, the calculation of GHG emissions based on fuel consumption records is straightforward. One simply takes the amount of fuel consumed in MMBtu or kg and multiplies by the appropriate emission factor. Using the per-MMBtu emission factor as an example, if a fleet owner operates 10 LPG vehicles and purchases 1000 gallons of LPG for each vehicle in a given year, the fuel consumed would be the following, assuming an energy content for LPG of 0.084 MMBtu/gallon:

10 vehicles x 1000 gallons/vehicle x 0.084 MMBtu/gal = 840 MMBtu per year

If we use the IPCC-derived emission factor for an LPG vehicle with advanced pollution control of 66,790 grams CO_2e/MMBtu, and a LPG-specific tailpipe GHG-to-total GHG correction factor of 15 percent (50 percent natural gas-derived LPG and 50 percent crude-derived LPG), the total annual GHG emissions would be:

840 MMBtu x 66,790 grams CO_2e/MMBtu x 1.15 =
64,519,140 grams (64.52 metric tons) CO_2e

To calculate emission reductions, one then compares the "project" emissions to those that would have taken place in the absence of the project, or the "baseline" emissions. To do this, we first assume that each "project" vehicle replaces a "baseline" vehicle, and that the distance traveled by each project vehicle is the same distance as would have been traveled by a baseline vehicle.

To calculate the baseline emissions one would have to first calculate the amount of fuel that would have been used in the baseline vehicles. If the project vehicles and the baseline vehicles are of the same efficiency, then the amount of fuel purchased in MMBtu would be the same in both cases. However, if the project vehicles are more efficient on a MPG-E basis, then the baseline vehicles will consume more fuel by a factor of η_p/η_b, where η_p is the fuel efficiency of the project vehicles and η_b is the fuel efficiency of the baseline vehicle.

Continuing the example above, let us now assume that the LPG "project" vehicles have a fuel efficiency of 26 MPG-E, and they are used to replace conventional gasoline vehicles with fuel efficiency of 22 MPG-E. The fuel consumed by the "baseline" vehicles would be:

840 MMBtu x 26/22 = 993 MMBtu per year

If we use the IPCC-derived tailpipe GHG emission factor for a gasoline vehicle with early three-way catalytic pollution control of 89,693 grams CO_2e/MMBtu, and a gasoline-specific tailpipe GHG-to-total GHG correction factor of 22 percent, the total annual GHG emissions for the baseline vehicles would be:

993 MMBtu x 89,693 grams CO_2e/MMBtu x 1.22 =
108,659,480 grams (108.66 metric tons) CO_2e

The GHG reductions resulting from the project can then be calculated by subtracting the project emissions from the baseline emissions:

108.66 – 64.52 = 44.14 metric tons CO_2e

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4 Climate Change Policy and the Emerging GHG Market

4.1 Introduction

This chapter describes the emerging market for GHG emission reductions and its relevance for the transportation sector. The intent is to provide the necessary market and policy background for those fleet owners and project developers interested in undertaking alternative fuel vehicle (AVF) projects, and generating GHG emission reductions that can be sold to an interested buyer in the market. The market is still in its very early stages of development, and only a few GHG emission reductions deriving from the use of AFVs have been traded on the market to date. Thus far, most of the trades have dealt with areas wherein the development of GHG emission reductions is relatively straightforward, such as the power sector, and the most common trades have involved renewable energy, waste-to-energy, and energy efficiency projects. However, given the growing fossil fuel use of the transportation sector and thus, the potential for GHG emission reductions, it is likely that transportation projects will generate significant GHG market activity, especially as the market matures, prices increase, and accounting methods are better defined.

The GHG market is not the only, nor even the most significant, driver in promoting the use of AFVs. This is especially true in the U.S. where no nationwide, mandatory regulations to reduce GHG emissions have been put in place for any sector. On the other hand, there is a wide range of regulations and incentives that directly mandate or indirectly encourage the use of AFVs. Traditionally, these incentives have been put in place with the specific goal of improving local air quality and decreasing energy dependence. However, in Europe and some US states, a few agreements and regulations have also been introduced with the specific goal of reducing GHG emissions. The various incentives for AFVs may take one of the following forms:

- Vehicle efficiency standards (in terms of miles per gallon) to reduce local air pollution and curb energy and particularly petroleum use;
- Mandatory AFV procurement policies to improve air quality and curb energy and particularly petroleum use;
- Criteria pollutant[45] tailpipe emissions *standards* to improve air quality;
- Pollution control *equipment requirements* to improve air quality; and
- Tailpipe emissions standards for GHGs (in terms of CO_2 emitted per mile) to directly address climate change.

In addition, the use of low polluting and alternative fuel vehicles is and will continue to be encouraged via financial incentives such as equipment rebates and tax breaks. These incentives may target alternative fuel development, alternative vehicle purchases, and development of alternative refueling infrastructure. Although not the main focus of this report, these drivers are important as they directly encourage and promote the adoption of AFVs. A detailed description of the various programs, regulations, and incentives that promote or require the procurement and use of AFVs in the U.S. is presented in Appendix A4.

[45] As specified by the 1990 Clean Air Act, criteria pollutants include carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM), lead (Pb), and Ozone (O_3).

The following sections describe the context of the GHG market, the trading mechanics within the market, examples of various government and regulatory programs that constitute the market framework, and the relevance of the market to the transportation sector.

4.2 The Emergence of a GHG Market

Over the past decade, the world community has introduced a mix of policies and programs to address climate change and limit growth in GHG emissions. These activities have included both voluntary and mandatory measures to control emissions and, in recent years, have made increasing use of market-based mechanisms such as emissions trading and investment in project-based emission reduction activities. These market-based programs enable governments and GHG-intensive industries to identify the most efficient and cost-effective opportunities to control emissions and meet emission reduction goals. They do this by first recognizing that a unit of GHG emitted in one place will have the same global effect as a unit of greenhouse gas emitted somewhere else. This in turn allows regulators to take a more holistic approach that sets emission reduction goals for an entire country or sector, as opposed to individual emitters. Finally, with a sector- or country-wide goal in mind, emissions trading encourages activities to be undertaken where it is most cost-effective to do so. The economic rationale behind emissions trading is that it will reduce the costs associated with achieving a set reduction of a given pollutant.

The GHG market is made up of sellers—parties that conduct and document GHG reduction activities—and buyers—parties that wish to purchase GHG reductions or emissions allowances. Sellers are those parties for whom enacting GHG reduction activities is less costly than the revenue generated by trading the resulting emission reductions or than the potential cost of regulation, such as an emissions tax or a penalty. Buyers are those parties for whom the cost of purchasing GHG emission reductions at market price is lower than the cost that would be incurred by undertaking emissions reduction activities internally (i.e. at a company-owned plant).

Market participants may be those regulated entities that are required to reduce GHG emissions or seek external emission reductions outside the entity boundaries to offset their own emissions. However, there are also voluntary participants in the market—both buyers and sellers—which may be motivated by any number of reasons, such as a desire to:

(a) hedge against the possibility of future regulations, either by making the predicted reductions that would be necessary under said future regulations, or by gaining experience with the process if the regulation comes about;
(b) reduce the long-term costs of controlling GHGs;
(c) receive financial benefits from environmentally sustainable practices through reduced energy costs, efficiency improvements, and raised productivity;
(d) gain first-mover advantages in the market for GHG emissions trading and influence policy decisions regarding development of future climate change policy and programs; or
(e) reduce emissions out of a genuine concern for the world's climate while enhancing the environmental reputation among stockholders, customers and employees.

Since there is no central recording entity for tracking GHG emissions transactions, the actual size of the GHG market is not fully known. However, as of the fall of 2002 it was estimated that approximately 280 GHG transactions have occurred since 1996, involving roughly 190 million metric tons of carbon dioxide-equivalent (CO_2e) emission reductions.[46] As indicated in Table 4-1, the price of trades in project-based emission reductions has ranged between US$0.50 and US$5 per metric ton of CO_2e, while the price of emissions allowances in the Danish and UK trading systems have ranged from US$2 and US$23. Most of these transactions have been between

[46] Frank Lecocq and Karan Capoor. "The State and Trends of the Carbon Market," PowerPoint presentation prepared for the World Bank PCF *Plus*, October 2002.

buyers and sellers in Europe and North America, and the majority of trades have been verified by independent third-party entities. At present, due to the diversity of the programs developed, no single GHG market or commodity has yet emerged and there is still limited information available on the size and prices of the GHG transactions. However, as these markets continue to develop and become more formalized,[47] the size, costs, and understanding of the trading mechanics and potential opportunities—including opportunities in the transportation sector—will continue to increase.

The most popular trading activities have included fugitive gas capture from landfills, fuel switching, energy efficiency, forestry and land use change, and co-generation. According to the World Bank PCF *Plus* research program, a few transactions based on transport-related emission reduction activities have also been reported in 2001 and 2002, representing about 4 percent of total volume traded through projects.[48]

Table 4-1. GHG Transaction Prices by Trading and Project-Based Programs [49, 50, 51]

Greenhouse Gas System	Price Per Metric Ton of Carbon Dioxide Equivalent (US$)
United Kingdom, Auction System	$23
United Kingdom, Emissions Trading System	$7-$18
Dutch Government ERUPT and CERUPT	$4-$5
World Bank Prototype Carbon Fund	$3-$4
Denmark, Emissions Trading System	$2-$4
North America	$1-$2
Other	$0.5-$5

4.3 Taking Advantage of the Market for GHG Emission Reductions

If an entity or project developer wishes to conduct a transportation project that reduces GHG emissions, participation in the emerging GHG emissions market will depend on the following factors:

- Is the entity or project developer in question regulated under an existing GHG program?

  None of the current GHG emissions regulations target emitters from the transportation sector, and therefore transportation entities will not be allocated allowances or be eligible to generate regulation-driven emissions reductions. However, transportation projects may be eligible for participation in programs that allow inclusion of project-based GHG offset activities.

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47 The markets become more formalized when regulations that call for GHG reductions are defined and become enacted.

48 Frank Lecocq and Karan Capoor, "The State and Trends of the Carbon Market," PowerPoint presentation prepared for the World Bank PCF *Plus*, October 2002.

49 Atle C. Christiansen, Overview of European Emissions Trading Programs, Point Carbon Presentation at EMA 6th Annual Fall Meeting & International Conference, 29 September -1October 2002. Toronto, Canada.

50 Frank Lecocq and Karan Capoor, "The State and Trends of the Carbon Market," PowerPoint presentation prepared for the World Bank PCF *Plus*, October 2002.

51 "ViewPoint: The UK ETS quieting down," ***Europe Weekly*** Point Carbon, 21February 2003.
http://www.pointcarbon.com(cannot find article on web site).

- Can it be documented that the emission reductions or the project itself would not have happened anyway? Is the entity already required by law to conduct the activity in question?

  For example, federal, state, municipal, and some private fleet owners in the U.S. are required by federal law to operate a certain percentage of alternative fuel vehicles (see Appendix A4). If an entity complies with this law, the GHG emission reductions are not eligible to be used as offsets; these reductions would not be considered "additional" to what would have occurred in a business as usual scenario. The concept of "additionality" is discussed in further detail in Chapter 5.

- In what geographical state and country is the entity located? Are there any GHG offset or registry programs within that state or country in which the entity can participate? Is the entity allowed to participate in programs in other states or countries?

Project developers should look at the description of each of the trading, offset, and registry programs listed below and decide whether their project would meet the corresponding eligibility requirements. Table 4-2 summarizes the major emissions trading and GHG offset programs around the world, and lists programs that include project-based emission reduction activities from the transportation sector. A project developer may also wish to contact an independent broker, who may have access to potential buyers.

Ultimately, the value of an offset or registered GHG reduction will depend on the degree to which it can be demonstrated that the reductions in question are real and additional, and have been verified as such. Chapters 3 and 5 describe the quantification steps that make emission reductions real, verifiable, and additional, and the process a project developer must undergo to document that this is so. As a general rule of thumb, the more accurate and verifiable a given GHG emission reduction activity is, the more value it will represent to a potential buyer, and that value will be reflected in the transaction price.

Table 4-2. Emissions Trading and Project-Based GHG Offset Programs

Program	GHG Offsets	Transportation Offsets	Projects Accepted to Date	Geographic or Other Restrictions
International				
PCF (World Bank)	Yes	Yes	7 (0 transport)	UNFCCC signatory countries only
ERUPT/CERUPT (Netherlands)	Yes	Yes	26 (0 transport)	Projects recognized by the Kyoto Protocol
United Kingdom, Emissions Trading	Likely	TBD	N/A	Projects in the UK only
Denmark, Emissions Trading	No	No	N/A	Utilities with operations in Denmark
PERRL (Canada)	Yes	TBD	0	Projects in Canada only
Australia GHG Abatement (GGAP)	Yes	Yes	10 (0 transport)	Projects in Australia only
EU Emissions Trading (2005)	Yes	TBD	N/A	TBD
INCaF	Yes	Yes		Projects recognized by the Kyoto Protocol

Program	GHG Offsets	Transportation Offsets	Projects Accepted to Date	Geographic or Other Restrictions
United States				
Oregon Climate Trust	Yes	Yes	6 (1 transport[52])	Preference to in-state and regional projects, but national and international projects as well
New Hampshire CO_2 Standard	Yes	TBD	0	Preference to in-state projects
Massachusetts CO_2 Standard	Yes	TBD	0	Projects approved by Massachusetts Department of Environmental Protection
Chicago Climate Exchange (CCX)	Yes	Not at this time.	0	US and Brazil, expanding to Mexico and Canada

4.4 GHG Emissions Trading and Project-Based Offset Programs

Many current approaches to mitigating the effects of climate change are based on the creation of a market for GHG reductions in order to allow for regulatory flexibility and to take advantage of the economic efficiencies that a market-based environmental regulation can offer. Such a system is based on the concept of emissions trading, or the creation of an emissions commodity which can be traded among qualified stakeholders. Emission commodities can either be created through the development of an emissions trading system, or through the establishment of programs to purchase and invest in project-based emission reduction activities. In the following, we describe each type of system and provide examples of each.

4.4.1 Emissions Trading

The economic rationale behind emissions trading is that it will reduce the costs associated with achieving a set reduction in greenhouse gases. Trading works by encouraging the covered participants with low-cost options to reduce their emission levels to below their allotted share and to make their surplus reductions available to participants with higher-cost reduction options. One framework for emissions trading is "cap and trade," whereby a regulatory authority establishes a permanent cap on aggregate emissions for a group of emitters. The cap may, for example, be set at a fraction of the historic emissions from the group of participants. The cap is divided into a set number of allowances, each of which gives the holder the right to emit a specified quantity of the regulated pollutant in a given compliance period.[53] In the case of GHG emissions, each allowance could grant the holder the right to emit, for example, one metric ton of CO_2 equivalent.[54] Once distributed among the participants, the allowances may be bought, sold, or (possibly) banked for future use. At the end of each compliance period, each participant must hold allowances equal to its actual emissions or else face a penalty. Although it has not been used to achieve a mandatory large-scale reduction of GHG emissions, the cap and trade system is not new, having been used in the United States since the 1990s to achieve reductions in stationary-source sulfur dioxide emissions.

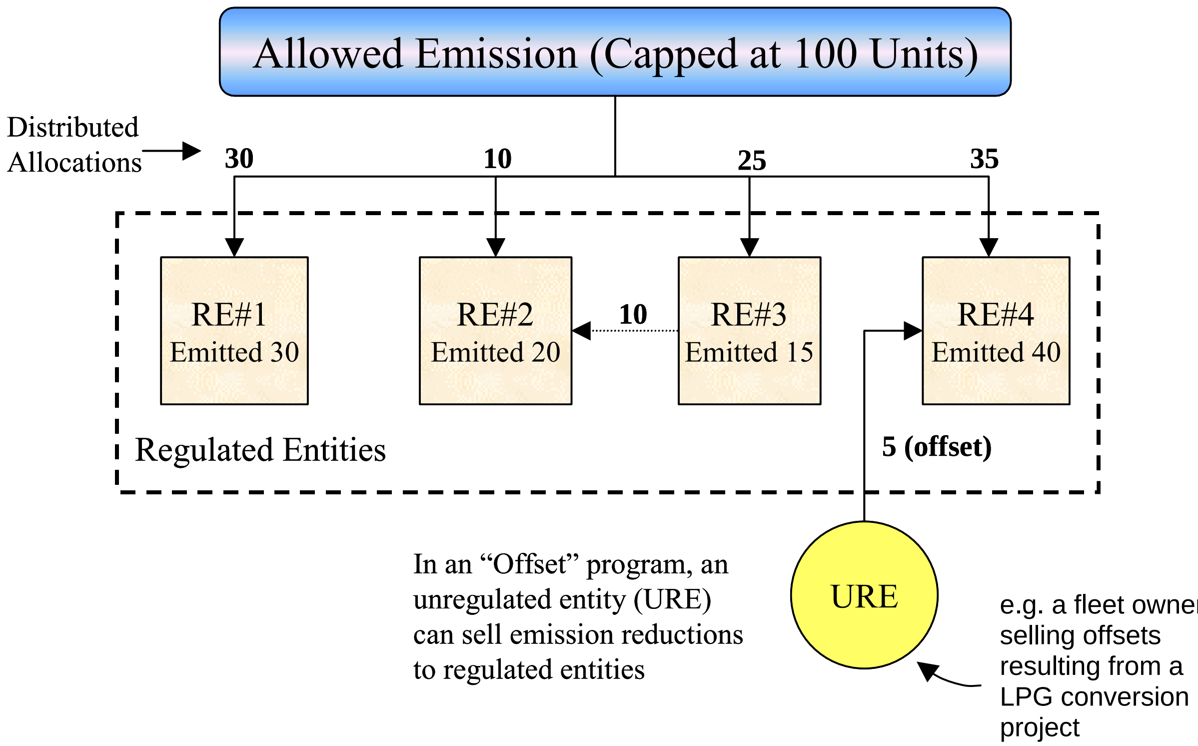
[52] Internet-based carpool coordination in the Portland area. Commuters use computers to quickly, easily, and safely arrange carpools.

[53] In some cases allowances are auctioned off and in some cases they are distributed based on a preconceived formula, such as historic emissions.

[54] One often sees the unit $MMTCO_2e$ which represents million metric tons of carbon dioxide equivalent. At times, units of MMTCE will be used, which stands for million metric tons of carbon equivalent. To convert from MMTCE to $MMTCO_2e$, multiply by 44/12, the ratio of the atomic weights of CO_2 and C.

Figure 4-1 is a simple illustration of a cap and trade system with offsets. In this case there is a regulated sector - the power sector - with regulated entities (e.g., power plants of a minimum size) to which emissions allowances are allocated by a governing body or regulator. In this example, we assume a total sector cap of 100 allowances. If a company exceeds its emissions allocations it may purchase allowances from another entity with surplus allowances. In the example, Regulated Entity 2 (RE#2) emitted ten units more than its allocated share of emissions and opted to purchase ten emissions allowances from RE#3 in order to meet its emissions target.

Figure 4-1. A Cap and Trade System with Offsets



If the system allows for the inclusion of project-based GHG offsets, then unregulated entities outside the emissions trading scheme may conduct and document emission reduction activities and sell these reductions to interested entities in the trading program.[55] In the example illustrated in Figure 3-1, Regulated Entity 4 (RE#4) emitted five units above its allocated target, and chose to offset those emissions by purchasing emission reductions generated by an unregulated entity (URE), or project developer, outside the trading system. Appendix 5 provides a more detailed overview of a potential trading system with offsets, and illustrates the various trading pathways that system participants may choose.

Other emissions trading systems exist which are similar to "cap and trade" but which differ in a few important areas. In these systems, emissions limits, standards, or reduction targets are imposed, but not in the form of an absolute cap on sector emissions. When reductions are made below the target levels, the result is a surplus of *emission reductions* that may be traded with other entities. Emission trading variants include:

- Baseline emissions trading systems, which set the emissions limit for individual entities below a level that would otherwise occur under business as usual. For example, a regulator may assign limits on GHG emissions to individual power plants based on

[55] Most trades will likely take place through an environmental commodities broker, which may be an independent commercial or non-profit or government controlled entity.

average emission levels of the previous five years. If the plant makes reductions beyond this limit, the surplus may be traded. Depending on the regulation, the plant may also purchase and apply offsets to stay within the emission limit.

- Rate-based emissions trading systems, which set emissions standards for production (e.g. per kWh or vehicle mile traveled) based on the level of output. Units could take the form of pounds of CO_2e per kWh of electricity produced, or per vehicle mile traveled. Entities that improve their efficiency beyond the target levels can trade the excess improvement with other companies. For example, the State of Oregon has mandated that emission rates from any new or expanded power plant proposed for operation in the state must attain a level of CO_2 emissions of 0.675 pounds per kWh, which is 17 percent below the most efficient natural gas-fired plant currently in operation in the United States. Zero-emission renewable plants would therefore generate emission reduction credits 0.675 pounds for each kWh of electricity generated. Proposed fossil plants would either have to use new technologies that achieve greater efficiencies than the existing standard or purchase CO_2 offsets.[56]

The following are GHG emission reduction programs with an emissions trading element, including mandatory cap and trade, baseline, and rate-based systems. Each is described briefly, highlighting the relevance of offsets and transportation projects.

- **Proposed European Union Emissions Trading Program.** In October 2001, the European Commission released a final proposal for establishing its own internal GHG emissions trading system. The first trial phase of the scheme would run from 2005 through 2007, regulating CO_2 emissions from all heat and electricity generators over 20 megawatts of rated thermal input capacity and from all refineries, coke ovens, iron and steel production processes, pulp and paper plants, and mineral industry installations. The transportation sector is excluded from this first trial phase, and it is uncertain whether it will be included in future. The second phase of the scheme would be concurrent with the first compliance period under the Kyoto Protocol (2008-2012), should it come into force, and each subsequent phase would last for 5 years. The system will require member states to distribute emissions allowances to individual entities that will then be allowed to use them to emit CO_2 or trade them to other entities throughout the EU. In the fall of 2002, the European Parliament and the Council of Ministers separately approved the Commission's proposal, with a number of amendments. The Directive is pending final approval by the European Parliament, but already one trade has been recorded in anticipation of the entry into force of the European system.[57] The EU Commission is in the process of developing a sister directive on the rules for including project-based GHG offset activities in the trading system, including the use of the Kyoto Protocol's Clean Development Mechanism (CDM) and Joint Implementation (JI). It is not yet clear to what extent transportation projects will be eligible. For further detail, see: http://europa.eu.int/comm/environment/climat/home_en.htm.

- **Danish CO_2 Emissions Trading System**. Currently, Denmark is the only country that has instituted a mandatory cap and trade system to reduce carbon dioxide emissions from electricity producers. In the Danish cap and trade system, the electricity sector as a whole was allocated a certain quantity of CO_2 allowances, starting with 23 million metric tons in 2000 descending to 20 million metric tons in 2003. Each electricity producer was allocated its share of allowances on the basis of the overall target and historical emissions at no cost. After the allocation, electricity companies are free to trade with each other. The penalty for noncompliance is the equivalent of US$6 per metric ton. The trading system became operational in April 2001 and will run through 2003. Denmark has not yet determined what

[56] Barry G. Rabe, "Greenhouse & Statehouse: The Evolving State Government Role in Climate Change," University of Michigan, Prepared for the Pew Center on Global Climate Change, November 2002.
[57] Point Carbon, "Shell Trading and Nuon Complete Historic First EU Emissions Trading Scheme Trade," 27 February 2003, < http://www.pointcarbon.com/article.php?articleID=2108> (12 May 2003).

will happen to the system after 2003 and is waiting for the final agreement on the EU trading system before making plans.

At this point in time, the Danish system does not allow for the inclusion of offsets, but rules for project-based emission reduction activities may be developed in the future. The degree to which transportation projects will serve as offsets, or whether any geographic restrictions will be placed on acceptable projects is yet to be determined. For more information, see: http://www.ens.dk/sw1084.asp.

- **The United Kingdom Emissions Trading System.** The UK GHG emissions trading scheme is the world's first economy-wide trading system. Under the British program, any company can opt to enter the trading scheme by negotiating energy efficiency targets or absolute emission reduction targets in return for incentives payments offered by the government. Thirty-four organizations have volunteered to be direct participants in the scheme, by taking on a legally binding obligation to reduce their emissions against 1998-2000 entity baseline levels. The scheme is also open to the 6,000 companies with Climate Change Agreements, which are negotiated agreements between business and Government to set energy-related targets. Companies meeting their targets will receive an 80 percent discount from the Climate Change Levy, a tax on the business use of energy. These companies can use the scheme either to buy allowances to meet their targets, or to sell any over-achievement of these targets. Anyone who does not want to enter the scheme on the basis of an emissions reduction target or project can simply open an account in the registry to buy and sell allowances. The Government is working on a framework to allow UK-based emission reduction projects to be included in the scheme. Thus, no offset projects are currently accepted in this system, but even when the offset component is incorporated, projects outside of the UK will not qualify.[58] For more information, see: http://www.defra.gov.uk/environment/climatechange/trading.

- In the U.S. state of **New Hampshire,** the Clean Power Act was signed into law by Governor Jeanne Shaheen on May 9, 2002 requiring the state's three existing fossil-fuel power plants to stabilize their CO_2 emissions at 1990 levels, which is approximately three percent below their 1999 levels, by December 31, 2006. Two of these plants, located in Bow and Portsmouth, use coal, and the third, located in Newington, uses oil and natural gas. All three plants are owned by Public Service of New Hampshire, a division of Northeast Utilities that also operates plants covered by the Massachusetts CO_2 rule described below.[59] The cap may be met by either installing new technology to reduce emissions or by purchasing offsets from other plants or a combination of the two. The law encourages reductions in New Hampshire by making it more expensive to buy offsets from entities outside the region. The law also includes incentives for energy companies to invest in energy efficiency, renewable energy, and conservation through offset activities, which may lead to increased funding for clean transportation projects. For more information, see: http://www.des.state.nh.us/ard/climatechange.

- The U.S. state of **Massachusetts** passed legislation that imposes a rate-based cap on CO_2 emissions from power plants operating in the state. The regulations cover six facilities, which account for 87 percent of GHG emissions from the state's power plants. The emissions rate is set at 10 percent below the current average emission rate. Depending on the chosen compliance strategy, deadlines for compliance range from 2004 through 2008. The targets can be met by using offsite reductions of CO_2 or by purchasing emission reductions from other GHG programs approved by the Massachusetts Department of Environmental Protection. In general, reductions from outside the power sector must be approved by the

58 United Kingdom Department for Environment Food and Rural Affairs, "UK Emissions Trading Scheme," <http://www.defra.gov.uk/environment/climatechange/trading> (12 May 2003).

59 Barry G. Rabe"Greenhouse & Statehouse: The Evolving State Government Role in Climate Change," University of Michigan, Prepared for the Pew Center on Global Climate Change, November 2002.

state as real, surplus, verifiable, permanent, and enforceable. As these regulations apply only to a handful of plants, there will be limited potential for large-scale trading, and offsets activities may play a more prominent role, including through the development of clean transportation projects. For more information, see: http://www.state.ma.us/dep/bwp/daqc/daqchome.htm

- **The Oregon Climate Trust.** Oregon has instituted an efficiency standard requiring new power plants to meet an emissions rate that is 17 percent more efficient than a natural gas combined cycle plant, measured in tons of CO_2 produced per kWh of electricity generated. Plants can meet this standard by improving efficiency, employing cogeneration (combined heat and power), or purchasing CO_2 offset credits. These offsets may be purchased directly from CO_2 reduction projects, or they may be purchased at a fixed price from a newly created NGO called the Oregon Climate Trust. The Oregon Climate Trust is an independent third party charged with purchasing CO_2 offsets from eligible projects to be sold to the regulated power plants or other interested buyers. It serves the dual function of promoting offset projects both within the state of Oregon and around the world, and providing a resource for regulated in-state power companies.[60]

  The Climate Trust is open to all types of offset projects, and has conducted one transportation project: an internet-based, carpool coordination system in the Portland area where commuters use the internet to quickly, easily, and safely arrange for carpools to reduce vehicle miles traveled. For more information, see: http://www.climatetrust.org/index.html.

- **Chicago Climate Exchange (CCX)**. Although the Chicago Climate Exchange is a voluntary emissions trading program for reducing GHG emissions, it is a form of self-regulation and is included in this subsection because of the potential for this program to contribute to the development of a GHG market in North America. In June 2001, 33 companies with assets in the Midwestern United States agreed to voluntarily commit to emission reductions and trading in six GHGs and classes of gases.[61] Participants committed to reducing their GHG emissions in 2003 through 2006, with targets of one percent below their baseline during 2003, two percent below baseline during 2004, three percent below baseline during 2005, and four percent below baseline during 2006. The baseline will be an average of annual emissions from 1998 through 2001. The geographic scope of the CCX covers emission sources and offset projects in the U.S. and Brazil. Sources and projects in Canada and Mexico are to be added during 2003.

  Examples of GHG mitigation and offset projects within the CCX include: switching to less greenhouse gas-intensive fuels; recovery and use of agricultural and landfill methane; vehicle fleet efficiency improvements; renewable energy systems such as wind and solar; energy efficiency process innovations; and carbon sequestration including no-till farming, agricultural grass and tree plantings.[62] For more information, see: http://www.chicagoclimatex.com.

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60 See Oregon Climate Trust website, at http://www.climatetrust.org.

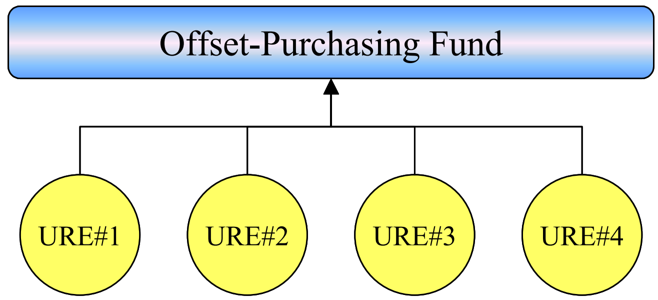
61 The six gases and classes of gases covered by the CCX are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

62 For more information on the Chicago Climate Exchange contact info@chicagoclimatex.com; Chicago Climate Exchange, 111 W. Jackson, 14th Floor, Chicago, Illinois 60604 USA; tel: (312) 554-3350; fax: (312) 554-3373; http://www.chicagoclimatex.com.

4.4.2 Project-Based GHG Emission Reduction Programs

Another policy approach to reducing GHG emissions is to establish an aggregate offset purchaser, which is usually a government or independent entity endowed with dedicated funds for the purchase of eligible project-based GHG reductions, as illustrated in Figure 3-2. Such a system would be voluntary and incentive-based, encouraging project developers to undertake emission reduction activities through the opportunity to earn revenue from the sale of the offsets.

Figure 4-2. Project-Based GHG Offset Program



(URE=Unregulated Entity)

For a project-based GHG emission reduction activity to qualify as an offset project, whether the offset is to be sold to a regulated entity or to an aggregate offset purchaser, it must meet a variety of qualifications set by the regulator of each program. Usually, the fund accepts project proposals that forecast the lifetime GHG reductions that are to take place as a result of the project along with a bid price for a unit of GHG that reflects the incremental revenue needed to make the project economically competitive. The lower the bid price, the more competitive the proposal is likely to be compared to other projects. For example, a project developer might submit a proposal to an offset purchasing fund describing a project that would reduce one million metric tons of CO_2e over a ten-year period at a bid price of US$3.50 per ton. If a similar project is bid that can make similar reductions for US$3.00 per ton, then, all things equal, the lower bid is likely to win. In some instances, purchaser preferences for a given project type (e.g. renewable energy) or geography (e.g. developing world) would tip the scales in favor of the more expensive bidder.

The following are examples of aggregate GHG purchaser funds and programs. Participation in these programs is voluntary and project-based.

- **The World Bank Prototype Carbon Fund (PCF)**. The PCF is an entity charged with the purchasing of GHG reductions from eligible projects within the framework of Joint Implementation (JI) and the Clean Development Mechanism (CDM) of the Kyoto Protocol. The PCF will invest contributions made by companies and governments in projects designed to produce emission reductions that are fully consistent with the emerging Kyoto Protocol framework. Contributors, or "Participants," in the PCF will receive a pro rata share of the emission reductions, verified and certified in accordance with agreements reached with the respective countries "hosting" the projects. The country where the project is to be located must be a signatory to the UNFCCC. Projects should start no later than December 2003, and be operational before January 2008. The estimated cost of emission reductions should preferably be less than US$3 per ton of CO_2e.

  The PCF has developed some of the most rigid criteria for project eligibility and documentation and in many regards will serve as the “Gold Standard” or upper limit for many of these qualifications and criteria. Transportation projects would be eligible if they satisfy the following technical requirements:

- The project should be replicable and/or facilitate technology transfer to the host country;
- The technology to be applied must be established and commercially feasible in a country other than the one where the project is to be held; and
- The project proposal should contain sample cases of the technology applied in the past in order to show its commercial feasibility.

To date the PCF has completed a total of seven projects, comprised of renewable energy and waste-to-energy activities. Seven more, which include cogeneration (combined heat and power) and energy efficiency projects, are under development. For more information, see: http://prototypecarbonfund.org.

- **Andean Development Corporation.** The Andean Development Corporation (Corporación Andina de Fomento or CAF) is a multilateral financial institution whose mission is to promote the sustainable development of its shareholder countries and regional integration. CAF's membership is currently composed of sixteen countries in Latin America and the Caribbean. Its principal shareholders are the five countries of the Andean Community (CAN): Bolivia, Colombia, Ecuador, Peru and Venezuela, as well as eleven extra-regional partners: Argentina, Brazil, Chile, Costa Rica, Jamaica, Mexico, Panama, Paraguay, Spain, Trinidad & Tobago, and Uruguay, and eighteen private banks from the Andean region. In May of 1999, with support from the Center for Sustainable Development in the Americas (CSDA), CAF established the Latin American Carbon Program (Programa Latino Americano de Carbono or PLAC) to assist its clients and shareholder countries to position themselves and participate in the development of emerging carbon markets. The primary objective of this initiative is to contribute to the establishment of the carbon market, to assist in the definition and development of innovative financial instruments and mechanisms, and to promote the participation of the private sector in this emerging market.

  In June 2001, and with the technical support of CSDA, CAF signed a purchase agreement with the Dutch government, which gives CAF the mandate to purchase €45 million (about US$41 million) worth of emission reductions in Latin America. The Netherlands will use the emission reductions to help meet its commitments under the Kyoto Protocol, while the increased availability of investment funds will support development of clean energy options in Latin America. CAF is currently purchasing these reductions mainly in energy sector projects. For more information, see http://www.csdanet.org.

- **The International Finance Corporation (IFC)—Netherlands Carbon Facility (INCaF).** INCaF is an arrangement under which the IFC will purchase GHG emission reductions for the benefit of the Government of the Netherlands. The Netherlands—which has allocated €44 million (about US$40 million) for the Facility over the next three years—will use the emission reductions to help meet its commitments under the Kyoto Protocol. The Facility will provide additional revenues to eligible projects that generate emission reductions in developing countries giving particular interest to financing projects of the following types (in order of preference): (1) renewable energy projects (e.g., biomass, wind, geothermal) that displace use of fossil fuels; (2) energy efficiency projects, supply side or demand side, that reduce consumption of fossil fuels; (3) recovery and utilization of methane from, for example, landfills and coal mines; and (4) switching from fuels with greater to lesser GHG intensity (e.g., from coal to natural gas). If a project is approved, the Facility will make payments to the project over a period of 7 to 14 years upon periodic (e.g.: annual) certification of actual GHG emission reductions. For more information, see: http://www.ifc.org/enviro/EMG/CarbonFinance/carbonfinance.htm.

- **The Netherlands's ERUPT/CERUPT Programs.** In anticipation of GHG reductions that will need to be made under the Kyoto Protocol, the Dutch Government has established the Emission Reduction Unit Procurement Tender (ERUPT) and the Certified Emission

Reduction Procurement (CERUPT) programs to purchase emission reductions from developed and developing countries, respectively. These reductions will be used against future requirements if the Kyoto Protocol goes into force, giving the Netherlands a head start in meeting its reductions. To date, the ERUPT/CERUPT programs have purchased offsets from over 26 projects, including wind, hydro, and biomass energy facilities, cogeneration plants, industrial energy efficiency, and waste-to-energy projects. At this time, transportation projects are not eligible under the ERUPT/CERUPT programs. For more information, see: http://www.senter.nl/asp/page.asp?alias=erupt.

- **Australia's GHG Abatement Program (GGAP).** This program, in operation since 2000, is similar to the Dutch ERUPT/CERUPT program in that it is an aggregate purchaser of GHG offset activities to be used to meet Australia's GHG emission reduction goals. The main difference is that it focuses on domestic projects only. GGAP will only support projects that will result in quantifiable and additional abatement not expected to occur in the absence of GGAP funding. Priority will be given to projects that will deliver abatement exceeding 250,000 metric tons of carbon dioxide equivalent (CO_2e) per year. Projects that do not meet this threshold but meet other criteria to a high degree may be selected.

  To date the program has funded ten successful projects dealing with cogeneration, landfill gas-to-energy and renewable energy projects, and industrial energy efficiency improvements. Although no transportation projects have been funded thus far, the program is a potential opportunity for viable transportation projects within Australia. For more information, see: http://www.greenhouse.gov.au/ggap/index.html.

- **Canada's Pilot Emission Removals, Reductions and Learning (PERRL) Initiative.** Through PERRL, the Canadian government plans to buy the rights to verified GHG emission reductions from eligible projects, each on a fixed price per ton basis. PERRL is open to provincial and territorial participation, and discussions are ongoing in order to determine the best way for them to partner with the federal government.

  In the fall of 2002, PERRL accepted bids for GHG removals and reductions from two types of projects: landfill gas capture and combustion, and CO_2 capture and geological storage. The government is expecting to be in a position to sign the first purchase agreements in 2003. Subsequent purchase rounds will focus on renewable energy and biological sinks, and may also return to landfill gas combustion and CO_2 capture and geological storage, time and budgets permitting. It has not yet been determined whether transportation projects will be permissible in the future. For more information, see: http://www.ec.gc.ca/perrl.

- **U.S. Climate VISION.** This program, which was launched in February 2003 by the Bush Administration, invites companies to set voluntary goals and targets for GHG reductions. This program is intended to help reach the Administration's national goal of reducing GHG emissions intensity by 18 percent by 2012. This is not an aggregate purchaser program, and there are no formal requirements for how the private sector may choose to meet specific intensity targets, but it is likely that some companies may opt to purchase GHG offsets on the open market to meet their goals. Thus, a U.S.-based transportation project might find an increased number of potential buyers, either directly, or via a brokerage, for the resulting GHG offsets. For more information, see:
  http://www.epa.gov/newsroom/headline_021203a.htm.

4.5 U.S. GHG Registries and Reporting Programs

Another option for project developers interested in documenting GHG reductions outside of direct participation in the GHG market is to register the emissions reductions in a registry or reporting program. A number of these registries and reporting programs have emerged in the U.S. over the past decade, with the goals of encouraging public and private entities to participate in GHG reduction activities and testing the procedures for GHG emissions accounting—a necessary prerequisite for emissions trading. Each program affords individual project developers with the opportunity to register and document activities that help reduce GHG emissions and possibly use the registered emission reductions against future regulatory requirements or in a future emissions trading regime. To register emissions in a registry or reporting program, the project developer would have to go through much of the same procedure as they would if they intended to have the reductions certified for sale on the market, only in the case of the registries the reporting requirements may be less stringent.

The different programs range in scope and project type, and do not all include activities related to transportation. Two leading programs—DOE's 1605(b) Program and the California Climate Action Registry—are described below. Various other State GHG emissions registries have also been proposed, as well as an alternate Federal registry under the new EPA Climate Leaders Program. Appendix A2 lists several new and proposed State initiatives to register GHG emission reductions, many of which encourage the development of GHG reduction measures that include the increased use of LPG vehicles.

- **U.S. Department of Energy's 1605(b) Voluntary Reporting of Greenhouse Gases Program.** Managed by the DOE's Energy Information Administration, the 1605(b) Voluntary Reporting of Greenhouse Gases Program (created under Section 1605(b) of the Energy Policy Act of 1992 (EPAct))[63] affords any company, organization, or individual with the opportunity to establish a public record of their GHG emissions, emission reductions, and/or sequestration achievements in a central and public database. The program first began accepting reports on GHG reduction activities during calendar year 1995 and was among the world's first registries set up to track voluntary GHG reduction activities.

  Like other registries, 1605(b) lays the foundation for maintaining information about individual projects and standardizing GHG emissions accounting methodologies, which in turn makes possible the creation of a market wherein GHG emission reduction credits can be traded. Reporters generally participate in the program to gain recognition for environmental stewardship, demonstrate support for voluntary approaches to achieving environmental policy goals, support information exchange, and inform the general public about GHG reduction activities.

  Data from the most recent 1605(b) reporting cycle, covering activities through 2001, were released by EIA in February 2003 and include considerable information on real-world transportation projects. Of the 66 transportation projects reported to the program, 3 were LPG vehicle projects involving direct and indirect emission reductions of approximately 600 metric tons of CO_2e. Appendix A3 presents summary information on these projects, including the entities that undertook and reported the project, the name, scope and general description of each project, and the methods used to estimate the achieved GHG emission reductions. The data reported to the program are publicly available on DOE's website and may be useful for educational and project replication purposes.[64]

  The 1605(b) program is currently undergoing a process of enhancement, as directed by President Bush in his February 14, 2002 Climate Change Initiative. The enhanced program is tasked with providing guidelines and recommended practices for more rigorous reporting that would facilitate the trading of transferable GHG reduction credits in the future. Guidelines, protocols, reporting forms and instructions, and database systems are currently being designed and developed for the enhanced 1065(b) program. The new program is expected to be launched in January 2004.

[63] Section 1605 of the Energy Policy Act of 1992 is available at http://www.eia.doe.gov/oiaf/1605/policy.html
[64] For more information, contact the 1605(b) Program's Communications Center at: 1-800-803-5182 or visit http://www.eia.doe.gov/oiaf/1605/frntvrgg.html.

- **California Climate Action Registry.** In September 2001 the California Senate passed Senate Bill 1771 to establish the California Climate Action Registry—a non-profit organization providing a central and standardized system for reporting annual GHG emission reductions. In return for voluntary registration of GHG emissions, the Registry promises to use its best efforts to ensure that participating organizations receive appropriate consideration under any future international, federal, or state regulatory regimes relating to GHG emissions.[65] California is taking several steps to address vehicular GHG emissions in transportation, and thus the Registry may gain increased prominence for transportation-related activities.

  At this point, the Registry does not accept reports that include only project-specific activities; however, rules for project-based activities are under development. In the meantime, companies that wish to report on their transportation-related activities also have to complete an inventory of company-wide emissions before joining the Registry and submitting a report.[66]

- **The Northeast States for Coordinated Air Use Management (NESCAUM)** is an interstate association of air quality control divisions in the Northeast states. The eight member states are comprised of the six New England states, as well as New York and New Jersey. It is the first association organized for the purpose of providing technical assistance and policy guidance on a regional basis to state air pollution control agencies. Several Northeast states have either adopted or are considering voluntary GHG "early action" registries. Further, the New England governors and eastern Canadian premiers adopted an action plan that calls for the exploration of a GHG registry and trading program. To coordinate and streamline these activities at the regional level, NESCAUM member states together with Illinois, Pennsylvania, and Wisconsin decided at a meeting in the spring of 2003 to begin developing a GHG registry and a regional trading program. It is expected that a platform for a regional trading system will be developed by 2004. As the registry and proposed trading program is still in the very early stages of development, the extent to which transportation programs will be addressed is still uncertain. For more information visit the NESCAUM website at: http://www.nescaum.org.

[65] California Energy Commission, Global Climate Change & California, <http://www.energy.ca.gov/global_climate_change/index.html> (12 May 2003).

[66] California Climate Action Registry, <http://www.climateregistry.org> (12 May 2003).

5 Procedures for Estimating and Reporting GHG Emission Benefits from LPG Vehicle Projects

This chapter covers some of the major issues related to the quantification of GHG benefits resulting from LPG vehicle projects for the purposes of reporting those emission reductions in the emerging GHG registries and reporting programs around the world. Although there is a great deal of experience with the use of alternative fuel vehicles, there is less experience in quantifying the associated GHG emission reductions and using them as GHG offsets. There are two reasons for this. The first is that, as a whole, the GHG market is still very young, and only a few project types—most of which deal with the power sector—have made any significant headway. Second, it is fundamentally more difficult to quantify and document the emission reductions from transportation projects as these projects involve a large number of individual vehicles and owners. Each vehicle will have a different performance characteristics, fuel efficiencies, and lifetimes, and each driver will have widely differing usage patterns and driving styles. It is crucial, therefore, that a well thought-out quantification and monitoring plan be developed at the outset of the project to ensure that the resulting calculations are accurate, real, and verifiable.

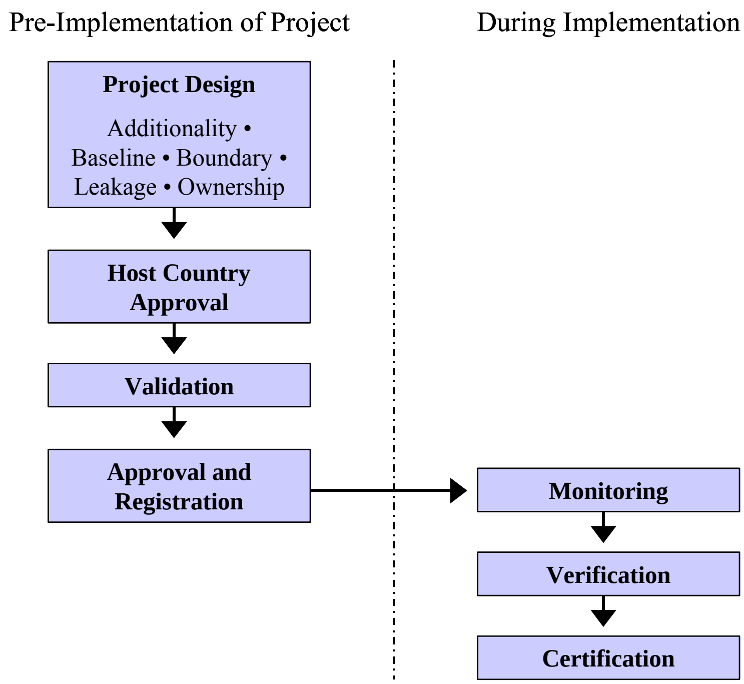
Each GHG reporting and offset program will have different criteria for participation and project approval, but there are a number of universal issues and basic requirements. The GHG quantification and project design steps described in the paragraphs below and used in the case study in Chapter 6 are common to most of the domestic and international programs that have been developed thus far, and therefore are a good representation of the required steps for GHG project development.

As a general rule of thumb, developers of GHG offset projects must first develop a plan that forecasts the emissions and emission reductions that will take place as a result of the project. Depending on the specific program under consideration, this plan may also include a methodology for monitoring and data collection so that the actual emission reductions can be calculated and verified. In the case of a transportation project, these data would likely come from such sources as fuel purchase records, odometer readings, and vehicle maintenance records. In many instances, the awarding of credits—if the program in question is designed to award credits—will not take place until after the reductions have taken place; that is, after the periodic project data have been recorded, verified, submitted and approved.

5.1 GHG Project Cycle Overview

In the process of developing a GHG reduction project for eventual certification, each registry, program, and project type will call for a unique set of requirements and procedures. However, among the various programs there are similarities that function to create a *de facto* framework for GHG project development. In this section we present this procedural framework, but urge the reader to keep in mind that this is merely a general summary of the common elements that exist across many of the existing programs, and that in order to participate in a specific program, the particular requirements of that program should be reviewed and observed. Figure 5-1 illustrates the major steps in the GHG project cycle, which include project design, host country approval, validation, registration, monitoring, verification, and certification.

Figure 5-1. The GHG Project Cycle



1. The first general step is the project design stage, which takes place before the project actually begins and involves most of the GHG quantification work. Contained within the project design is the screening for additionality, the projection of a baseline, and delineation of the contractual issues that will determine the eventual ownership of the emission reductions or offsets. These design issues will be described in more detail later in this section.

2. Second, if the project is intended for participation in one of the international programs set up to implement the UNFCCC,[67] the project must also gain host country approval from the national authorities specifically authorized to approve GHG projects.

3. The third step is the validation of the project proposal, where an independent party reviews the project design, confirms that the quantification procedures and assumptions made are reasonable, and verifies that the project, absent any unforeseen factors, will achieve its goals. This step, which takes place before the project is accepted into a program, is only required by some of the many GHG programs introduced to date. The most notable of these include the World Bank Prototype Carbon Fund (PCF), the Clean Development Mechanism (CDM), and the Dutch ERUPT/CERUPT (see Subsection 3.4.2).

4. The fourth step involves the project approval and registration by the program itself. During this stage, program administrators determine whether or not the proposed project meets all of the program-specific criteria and whether it can be accepted into the program. This step is common to all programs and is necessary before project implementation and accrual of emission reductions can begin.

5. Fifth, once project implementation has been initiated, most programs require project developers to monitor the emissions performance of the project while it is underway. This is

[67] International project-based programs to implement the UNFCCC include the AIJ Pilot Phase, JI and CDM of the Kyoto Protocol, and the PCF and Dutch CERUPT/ERUPT programs, which are designed to be compliant with the Kyoto Protocol. (See Chapter 4 for further discussion of these programs.)

where the project developer/manager collects the data that quantify the actual GHG emission reductions relative to the projected emission baseline.

6. Next, the project developer/manager submits the documented results of the monitoring activities to a third party for auditing and verification that the emission reduction claims are accurate. Although the verification step is required by more programs than the validation step, it is still not used for all GHG programs, trading or offsets purposes. Still, it is an important function, which increases the credibility of the claimed reductions and may lead to as much as a 30 percent increase in the value of the reductions when traded in the carbon market.[68]

7. Finally, in some cases, the project developer or an independent verification body is also required to submit a written certification of the achieved emission reductions to the program administrator before potential recognition or credit is awarded to the project. Programs may either use this step in place of the verification process, as in the case of the current U.S. Department of Energy's 1605(b) Voluntary Reporting of Greenhouse Gases Program, or it may be used in conjunction with an independent verification opinion.

5.2 Project Design

The most important GHG quantification steps are addressed during the design of the project itself, as they are necessary for determining the project's emission benefits and eligibility as a GHG offset project. The following subsections introduce the major quantification steps required by most GHG reporting programs: additionality, emissions baseline, project lifetime, project boundary, leakage, and ownership.

5.2.1 Additionality

Many projects that result in lower GHG emissions have associated cost savings and energy benefits or may be required by some current or future environmental law, making it likely that they would be implemented even without the added incentive of carbon revenue or financing or GHG regulation. To encourage real emission reductions and ensure the integrity of a GHG program, it is therefore vital to make sure that recognition is awarded only to those emission reduction activities that are *additional* to the business-as-usual scenario.[69] This means that project developers must demonstrate that emission reductions associated with their project would not be implemented in the absence of the specific GHG offset program or the potential carbon financing.

However, determining what may or may not happen in the future is a difficult, costly, and sometimes contentious process, and different GHG programs have applied different criteria for testing additionality with the goal of striking a balance between environmental integrity and reasonable transaction costs. Some of the different ways of testing additionality include:

- *Environmental additionality test:* This test would accept all projects resulting in GHG emissions that would not have occurred otherwise; i.e. in the absence of the project.[70] In this

[68] Wiley Barbour and Gordon R. Smith, "Suggestions for Accounting for GHG Emissions Offsets Generated by Agriculture," Environmental Resources Trust, presented at USDA Workshop on Accounting Rules and Guidelines for Agriculture Greenhouse Gas Activities, Washington, D.C. 14-15 January 2003, <http://www.usda.gov/oce/gcpo/WkshopPresentations.htm#Agriculture> (12 May 2003).

[69] The additionality criterion is particularly important in systems where there are no binding emission limits. A weak additionality screen could thus increase global emissions and undermine the integrity of the entire system by shifting investment towards business-as-usual projects in developing countries.

[70] For example, the CDM accepts a project activity "if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity." UNFCCC "Project Activity Design Requirements: Project Activity Baselines," <http://unfccc.int/cdm/baseline.html> (12 May 2003).

case, the additionality of the project activity is determined by comparing the emissions of the project to that of the "without project" or baseline scenario, and only recognizing emission reductions that exceed the baseline scenario. The eligibility of the project is thus directly linked to the procedures used for quantifying the baseline.

- *Surplus/regulatory test:* This test involves screening out any projects that are already required by existing regulatory and policy measures, and/or supported by official development assistance. LPG vehicle projects in the U.S. that are already mandated through the different Federal and State programs for alternative fuel vehicle programs described in Appendix A2 would therefore *not* pass the surplus/regulatory additionality test.

- *Financial test:* This test considers projects additional if, and only if, they would not have occurred without the financial incentive available through the GHG program. This type of testing would typically employ the net present value (NPV), internal rate of return (IRR), or the level of financial risk associated with the project as a metric to determine the economic attractiveness of the project relative to viable alternatives in similar markets.

- *Barrier test:* Another approach involves examining whether any potential market or institutional barriers are preventing this type of project from being implemented. In the case of transportation projects, barriers may include the lack of a supporting refueling infrastructure or an absence of mechanics with relevant LPG vehicle expertise.

In addition to the various proposed additionality tests outlined above, a group of environmental organizations, spearheaded by the World Wildlife Fund (WWF), have developed a draft "Gold Standard" for determining the additionality of project-based GHG emission reduction activities.[71] This Gold Standard, which is described further in Box 5.1, applies very conservative and environmentally stringent criteria, but may serve as useful background information on the types of questions that will need to be addressed when considering the use of LPG vehicles as a GHG offset activity. In general, the WWF Gold Standard is more conservative than the criteria used by most of the existing GHG offset programs.

Ultimately, project developers should refer to the guidance of the specific GHG program in question for exact information on how to address the question of additionality.

Box 5.1 WWF Gold Standard for GHG Offset Projects

The Gold Standard for GHG offset projects was developed by the World Wildlife Fund (WWF) in consultation with a range of environmental, business and governmental organizations and presented for public comment in October of 2002. The aim was to establish an independent best practice benchmark for project development while the rules for additionality and baseline are still being developed.

According to the draft Gold Standard, GHG offset projects are additional if they demonstrate that:

- No similar projects in terms of technology, fuel, size, site and process have been commercially implemented, without carbon finance, in the region in the previous 5 years.
- The project has not been publicly announced prior to its development as a GHG offset project, unless formally cancelled, with a clear explanation why.
- Barriers to finance or broader implementation–such as institutional blockages and lack of project finance–are being removed.
- The baseline is either watertight or the most conservative applicable.
- Official development assistance is not used to purchase the GHG offsets.

[71] World Wildlife Fund, "Gold Standard: Quality Standards for CDM and the JI," October 2002, <http://www.panda.org/downloads/climate_change/cop8standards.pdf> (12 May 2003).

5.2.2 Project Boundary and Relevant Greenhouse Gases

The project boundary refers to the particular sources and sites of anthropogenic (human-caused) GHG emissions that are included in the calculation of GHG emission benefits. Most GHG offset programs require that all anthropogenic GHG emissions associated with the project that can reasonably be accounted for should be included in the calculation of emissions benefits.

In the case of both LPG and gasoline vehicles, most of the associated GHG emissions are emitted during the operation of the vehicle and, of these, CO_2 is by far the most significant contributor. As described in more detail in Chapter 4, CO_2 makes up about 95 percent of total GHG emissions. This raises the question of whether it will be sufficient to compare fuel consumption from vehicle operation only, or whether upstream emissions from the transportation and processing of the fuel should be included as well. Due to the difficulty of accurately identifying all upstream sources within a reasonable budget—particularly in many developing countries where information on upstream emissions is limited—some studies recommend focusing on tailpipe emissions only.[72,73] Other programs have found it sufficient to report only on changes in CO_2 emissions, while leaving out the less significant emissions of CH_4 and N_2O.[74]

As only a few transportation projects have ever been reported to a GHG offset program, there is little guidance available on how to establish boundaries for vehicle fuel switching projects. The few studies that have examined GHG emissions for transportation projects recommend focusing only on GHGs emitted during vehicle operation.[75] However, some project developers and GHG offset projects may also choose to include upstream emissions to improve the accuracy of the reported GHG reductions. This can be done by using a default upstream correction factor, as described in Chapter 3.

5.2.3 Leakage

Leakage is the indirect effect of emission reduction policies or activities that lead to a rise in emissions outside the project boundary. For example, fossil fuel substitution, such as increased use and availability of LPG, may lead to a decline in fuel prices and a rise in higher-emitting fuel use elsewhere. Project developers are often required to provide evidence that the emission reductions achieved at the project site do not lead to increases in emissions outside the boundaries of the project, or that the baseline calculation of claimed emission reductions quantifies and accounts for such leakage.

5.2.4 Ownership

Most programs require that the project developer, or those seeking claim to potential GHG reduction credits, have a legitimate right to ownership of the reductions generated by the project and that other potential claimants be identified. Ownership can be demonstrated through documents certifying and dividing ownership clearly among all project participants. If necessary, supporting documents by local or national government authorities can be included to verify the

[72] "Determination of Baselines and Monitoring Protocols for Non-LUCF Projects," Prepared by EcoSecurities with contributions from SGS on contract to the UK Department of Environment, Food and Rural Affairs , June 2002.

[73] "Greenhouse Gas Emission Reduction Project: Fueling of New Compressed Natural Gas Powered Vehicles," Case study prepared by KeySpan Energy Corporation and reported to NESCAUM, <http://www.nescaum.org/Greenhouse/Private/GHGNGV.doc> (12 May 2003).

[74] "RABA/IKARUS Natural Gas Engine Project" in Hungary funded by project developers in the Netherlands and reported under the AIJ Pilot Phase. For more information refer to 1997 progress report submitted to the UNFCCC, <http://unfccc.int/program/coop/aij/aijact/hunnld01.html> (12 May 2003).

[75] "Determination of Baselines and Monitoring Protocols for Non-LUCF Projects," Prepared by EcoSecurities with contributions from SGS on contract to the UK Department of Environment, Food and Rural Affairs , June 2002.

validity of claimed ownership. The issue of ownership is an important consideration for transportation projects, especially in those cases where buses and taxis are owned by individual vehicle operators rather than one single fleet operator. When a transportation project is divided among several vehicle owners, contractual and other issues in terms of who will own the resulting GHG credits may become very complicated. One solution for this type of project may be to form an association representing all the vehicle owners, which could then be listed as the owner of the project. In the case where a single company provides the financing for vehicle conversions from gasoline to LPG, this company could also claim ownership of the resulting emission reductions.

5.2.5 GHG Emission Baselines

Project-based programs typically measure GHG emission reductions by comparing the projected business-as-usual emissions, or the "without project" emissions as the baseline, against the emissions that actually take place with the project in place, or the "with project" emissions. The emission baseline is the counterfactual business-as-usual scenario that the actual emissions will be measured against to determine the reductions that take place as a result of the project. The challenge in developing emission baselines stems from the uncertainty of projecting what will happen in a given economy or specific market 5, 10, or 20 years into the future.

There are two general types of emissions baselines: static and dynamic. As their names suggest, static baselines (see Figure 5-2) assume a given annual emissions rate (in tons of CO_2 equivalent per year) that is unchanging throughout the life of the project, while dynamic baselines are designed to vary in future years to account for projected changes in the business-as-usual scenario (see Figure 5-3). Depending on individual program rules, both types of baselines may be revised at some future date to account for changes that have taken place in the interim.

Figure 5-2. Sample Project A: Static Baseline Case

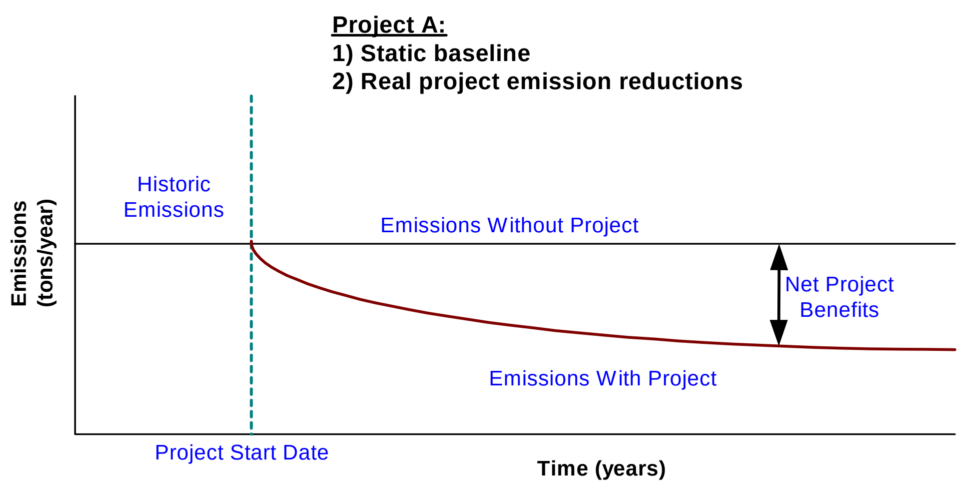
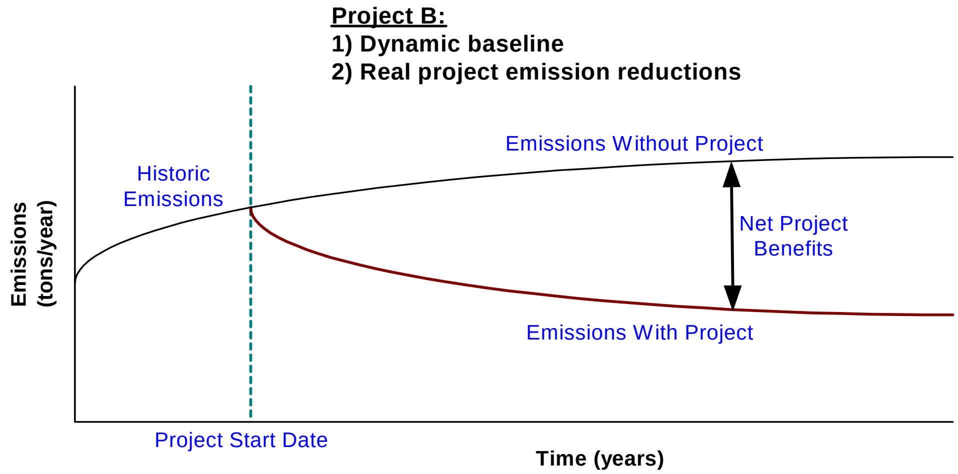


Figure 5-3. Sample Project B: Dynamic Baseline Case

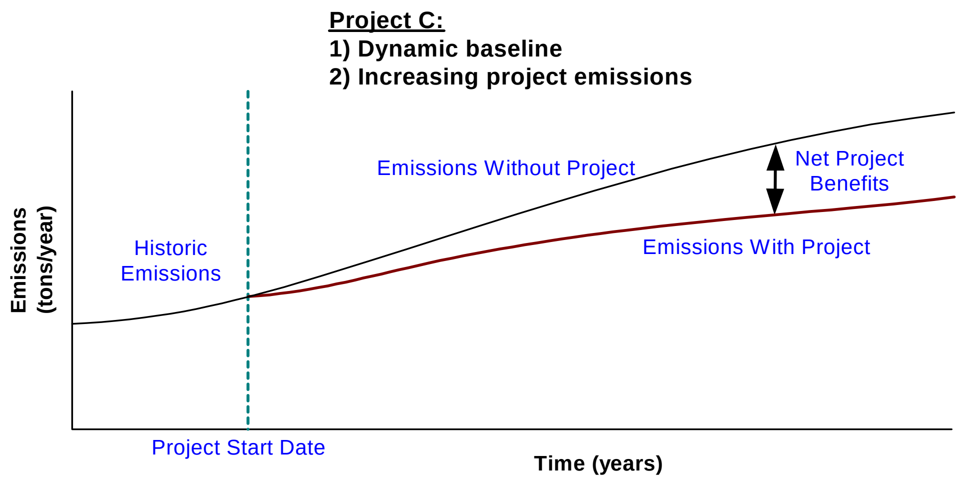


Static baseline emission rates are often based on (a) existing actual or historical emissions from a given sector (e.g. electricity), entity (e.g. company), facility (e.g. power plant), or vehicle, or (b) emissions from a technology that represents the most likely course of future action based on what is economically attractive, taking into account barriers to investment, and so on.

Dynamic baselines will likely use the same factors as static baselines for their initial emission rates, but are also linked to particular variables—such as planned legislation, technology market penetration, economic growth rates, or technology efficiency rates or standards—that are likely to change as the project lifetime evolves. For example, a law enacted sometime in the future mandating use of a given technology or fuel option will dramatically alter the use of that technology or fuel and the associated emissions levels. In this case, an accurate baseline would either forecast such a law and its effects, or it would be revised to account for it.

Once the baseline has been determined, the estimate of emissions "with the project" can be developed. Most project cases lead to *real* emission reductions. However, as illustrated in Figure 5-4, it is sometimes possible that actual emissions with the project will continue to rise above historical emissions. For example, emissions from vehicles retrofitted to use LPG instead of gasoline may result in increased emissions due to the normal efficiency losses of aging vehicles, but will still lead to overall emission reductions because of the switch to LPG. Such projects may still be able to obtain GHG reduction credits, as long as the reported project emissions performance continues to fall below the emissions associated with the baseline scenario.

Figure 5-4. Sample Project C—Dynamic Baseline with Increasing Project Emissions



5.2.6 Monitoring Plan

Many GHG offset programs require project developers to submit, as part of the project development documentation, a monitoring plan that states which data are to be collected, how the data collection is to take place, and how the collected data will be used to calculate overall emission reductions. In the case of a vehicle fuel switching project, the data assessed would likely come from fuel purchase records, odometer readings, and/or vehicle maintenance records. Depending on the stringency of the program in question, the degree of monitoring required, in terms of the frequency and detail of the data to be recorded, can widely vary.

5.3 Validation and Verification

Some GHG offset programs also require periodic, independent verification of the monitored emission reductions that have occurred as result of the registered offset project. Depending on the stringency required by the program, the verification could involve a simple desk-review of monitored data or it could entail physical, on-site inspections and, where useful, interviewing of relevant personnel. The verification may be applied to each and every vehicle in the project or to a fraction of the vehicles chosen randomly or selected according to agreed-upon criteria. If verification procedures are not already specified by the GHG program in question, project developers may be required to develop a plan for having their emission reductions reviewed and verified by a third party.

A few programs, such as the Dutch CERUPT and the World Bank PCF, also require that projects in developing countries get their project baseline and quantification procedures independently validated prior to acceptance into the program. These programs have developed specific validation protocols to which project developers and validators can refer.

6 Case Study: Quantifying GHG Emissions From LPG Vehicles—Mototaxis in Pucallpa, Peru

In Chapter 4, the process for developing and using emission factors to quantify GHG emission reductions resulting from LPG vehicle projects was described. In Chapter 5, an outline was presented of the various stages and considerations for developing a GHG emission reduction project, estimating the GHG emission benefits, and participating in a GHG offset program or registry.

In this chapter, the methodologies and considerations described in the previous sections are applied to a case study of a potential LPG-conversion GHG reduction project in the city of Pucallpa, Peru. The data used for the case study are based on information collected from an ongoing LPG-conversion project in Pucallpa where 1,700 gasoline-fueled motorcycle taxis, called mototaxis, are already being converted for LPG use. As this project is already occurring it is *not* being considered for use as a GHG reduction project. However, we are using the efficiency and fuel use data from these ongoing vehicle conversions as background information for quantifying the potential GHG emission reductions that could be achieved by converting up to 20,000 *additional* gasoline-fueled mototaxis to LPG. Thus, although the quantification of GHG emissions presented in the case study is based on actual data gathered from the developers of the current mototaxi project, the case study itself is hypothetical because no one, at this point in time, has prepared and submitted any project documents to any existing GHG trading or offsets programs.

This case study is a good illustration of the type of project that may generate GHG reduction offsets. The steps and considerations are those that other project developers with similar projects would need to go through in order to document GHG offsets that may be registered or traded in an emissions trading program. In addition, the project-specific nuances illustrate the types of considerations and decisions that a project developer will likely encounter.

6.1 Regional and Regulatory Background

Peru's total primary energy consumption (TPEC) is about 260,000 barrels of oil equivalent (BOE) per day.

Figure 6.1 offers a comparison of Peru's TPEC with other selected North and South American countries. Peru's fuel mix is approximately 20 percent non-commercial fuels (mostly firewood) and 80 percent commercial fuels, of which crude oil-refined products (gasoline and diesel) make up 57 percent of the TPEC, LPG makes up 4 percent, natural gas makes up less than 1 percent, and hydro-electric makes up 12 percent. The residential, transport, and industrial/mining sectors account for 35, 31, and 27 percent of Peru's energy use, respectively.

Figure 6-1. Total Primary Energy Consumption of Selected Countries[76]

Country	2001 BOE/day
United States	45,877,662
Canada	5,913,751
Brazil	4,150,498
Mexico	2,836,331
Venezuela	1,394,530
Argentina	1,257,440
Colombia	534,176
Chile	501,085
Peru	***259,997***
Cuba	184,362

In 2000, Peru imported 58,553 BOE per day of crude oil, representing 43 percent of total Peruvian oil demand, and 9,064 BOE per day of mineral coal, representing 98 percent of coal demand. On average, 28,985 BOE of natural gas is produced per day, although 21,287 BOE per day is re-injected back into the field due to lack of gas markets. The remaining gas is used for power generation at an average electrical efficiency of 23 percent.

Pucallpa is located about 250 miles to the Northeast of the capital, Lima, along the Ucayali River in the Amazon basin, and has a population of 221,000 in the city and 266,000 in the region. There are about 26,000 mototaxis in the Pucallpa region where the LPG conversion project is being considered, all of which currently run on leaded gasoline. LPG is widely available in the region and is comprised of approximately 55 percent propane and 45 percent butane, with an energy content of 95,617 Btu per gallon. Unleaded gasoline is also available, albeit at a much higher cost.

Table 6-1. Fuel Energy Content of Fuels Used in Pucallpa (Btu/Gallon)

Leaded Gasoline	Unleaded Gasoline	LPG
117,810*	115,500**	95,617***

* Assumes that leaded gasoline has an energy content that is 2 percent greater than unleaded gasoline.[77]

** Default parameter from Chapter 1.

***Aguaytia Energy.

A new law is to take effect in December 2004, which mandates the phasing out of leaded gasoline over a nine to twelve month period. Without modification to the vehicles, the replacement fuel would likely be high octane unleaded gasoline, which in Pucallpa is about 12 percent more expensive than leaded gasoline. LPG, on the other hand, is about 29 percent cheaper than unleaded gasoline on a per-unit-energy basis, as shown in Table 6.2. Natural gas may also be competitive, but the development of a natural gas distribution infrastructure would require explicit government sanctioning. The option of installing additional natural gas infrastructure is currently under investigation, but would only be considered in the medium to long term (say, after 2007).

[76] U.S. Energy Information Administration,
http://www.eia.doe.gov/emeu/international/total.html#IntlConsumption;
http://www.eia.doe.gov/emeu/cabs/peru.html.
[77] Ibid.

Table 6-2. Price of Fuels in Pucallpa

Leaded Gasoline	Unleaded Gasoline	LPG
US$2.47/gallon	US$2.76/gallon	US$1.43/gallon
US$20.97/MMBtu	US$23.90/MMBtu	US$14.96/MMBtu
--	14% more than leaded gasoline on a per MMBtu basis	29% less than leaded and 37% less than unleaded gasoline on a per MMBtu basis

6.2 Project Description

The potential GHG offset project would involve the conversion of up to 20,000 individually owned mototaxis to run on LPG. This number would be in addition to the 1,700 mototaxis currently being converted to LPG through subsidies provided by an LPG supplier in the region. The taxis currently run on leaded gasoline. The mototaxis are four stroke, 1.25 liter engine motorcycles with an attachment on the back for three passengers plus the driver (see Figure 6-2). The physical specifications are listed in Table 6-3.

Figure 6-2. Sample Mototaxi in Pucallpa, Peru[78]

Table 6-3. Mototaxi Specifications

Vehicle Specifications			
Engine Type	4 stroke	Brakes (Front/Rear)	Drum
Cooling Type	Forced Air Cooled	Fuel Tank Capacity	8 litres
Displacement	173 cc	Reserve Capacity	1 litres
No. of Cylinders	1	Wheel Base	2000 mm
MaxPower	8.17 bhp	Ground Clearance	200 mm
Max Power RPM	5000 rpm	Minimum Turning Radius	2.88 m
Max Torque	11.5 N-m	Curb Weight	295 kg
Max Torque RPM	4000 rpm	Maximum Payload	335 kg
Carburetor	Keihin M10 A	Fuel Efficiency (Ideal)	33 kmpl
Transmission Type	4 forward and 1 reverse	Fuel Efficiency (Highway)	28 to 32 kmpl
Clutch Type	Wet multidisc type	Fuel Efficiency (City)	28 to 32 kmpl
Electrical System	12V DC	Max Speed	55 kmph

[78] Courtesy of Aguaytia Energy del Perú, S.R.L.

As this is a hypothetical project, no project developer or owner has been defined. However, the project could potentially be conducted by an independent non-profit organization, an association of mototaxi owners, or a wholesale natural gas and LPG supplier. Aguaytia Energy, a Peruvian wholesale natural gas and LPG supplier, is subsidizing the current effort to convert 1,700 mototaxis in Pucallpa, and estimates the cost of a single vehicle conversion to be US$240, which will likely make the conversions prohibitively expensive for individual owners, as access to upfront capital is limited. Therefore, it is likely that the project developers of a new conversion project would have to secure financing to subsidize about 75 percent of the conversion costs, leaving 25 percent to the vehicle owner. The financing of this subsidy will be the ultimate determinant in the rate and quantity of conversions that can take place. Depending on the financing structure of the potential GHG offset project, the vehicle conversions could either be undertaken all at once or during a staged process spanning several years in order to allow the project developers to raise funding while the project is being implemented.

6.2.1 Ownership of Resulting GHG Emission Reductions

In order for the project developers to apply for participation in a GHG offset program they would need to take the necessary legal steps to ensure that there are no disputes over the ownership of the potential GHG emission reductions achieved by the project. Since the financing for the mototaxi conversions is likely to be provided almost entirely by the project developers, they would be the likely owners of the GHG emission reductions. However, the project developer would need to enter into a legal agreement with each vehicle owner stipulating that in exchange for the financing of the vehicle conversion, the vehicle owner will forfeit all rights to any ensuing GHG emission reductions. It is unlikely that an individual vehicle owner would challenge the project developer’s rights to the emission reductions, since on a per-vehicle basis the volume and value of the GHG reductions would be minimal. However, a legal contract could provide a low-cost assurance against a potential challenge by individual owners claiming ownership of the GHG credits. Moreover, with the ownership rights belonging to a single entity, contract negotiations with a potential purchaser of the emission reductions would be much simpler.

6.2.2 Benefits to the Vehicle Owner and the City of Pucallpa

A conversion from leaded gasoline to LPG would deliver significant benefits to both the vehicle owners and the Pucallpa region. Vehicle owners would save money on fuel consumption, motor oil consumption and vehicle maintenance, and the vehicles would last longer. The region of Pucallpa would benefit from significantly reduced air and water pollution.

It should be noted that if the LPG vehicles were compared to high-octane unleaded gasoline vehicles, the benefits would be less pronounced. Since only limited testing on unleaded mototaxis in the region has been performed, it is impossible to know to the exact benefits of using unleaded gasoline.

Reduced Fuel Consumption. In most cases, the efficiency of an LPG vehicle is on par with that of an unleaded gasoline vehicle. However, because of the low octane and low-grade gasoline currently used in the region, the mototaxis tend to burn rich air/fuel mixtures, and thus consume more fuel. According to Aguaytia Energy, using the higher octane LPG would increase fuel efficiency by as much as 35 percent, on a miles-per-MMBtu basis.

Reduced Consumption of Motor Oil. Currently, mototaxi owners using leaded gasoline must replace their motor oil once every three days. This high replacement rate is due to several factors, including the high ambient dust content, unpaved and uneven roadways, and high levels of carbon buildup in the engines. The high level of carbon buildup is partly due to the fact that the gasoline contains lead and consists of a low grade and octane, and that the vehicles are typically overloaded. As a result, the vehicles run using rich air/fuel mixtures, producing larger quantities of carbon, which get into the air and the engine. By using higher octane LPG, the vehicles would run more cleanly and develop less carbon buildup. Based on experience with current LPG-conversions, Aguaytia estimates that the required rate of oil changes would decrease to once every 10 to 15 days after the mototaxis have been converted to LPG. Thus, over the course of a single year, a vehicle owner using LPG can expect to use, and dispose of, between 85 and 97 liters of motor oil less than an owner of a leaded gasoline taxi. For 20,000 vehicles, this would represent a savings (of both consumption and disposal) of almost 2 million liters of motor oil per year.

Reduced Maintenance and Extended Vehicle Life. Currently, the mototaxis are overhauled once every six months, which includes replacing the pistons, rings, gaskets and valves, and cleaning the engine. After four of these overhauls, the vehicle life is extended by re-boring the engine and putting in new cylinder sleeves and pistons. The reduced carbon buildup associated with the use of LPG would keep the engine cleaner and significantly reduce the frequency of the overhauls, thereby reducing maintenance costs and extending the overall life of the vehicle.

Reduced Air Pollution. Since the vehicles would operate using leaner air/fuel mixtures when running on LPG, they would emit lower levels of local air pollutant emissions such as CO and particulate matter. Local air pollution would be further reduced due to a more optimized air/fuel ratio that can be achieved with LPG, and the fact that the fuel contains no lead. The overall extent of the reduced air pollutants will likely be significant, but since no project-specific vehicle emission characteristics have been yet been documented, it is difficult to quantify an estimate.

Reduced Water Pollution. Much of the used motor oil from the mototaxis is dumped indiscriminately in the local waterways, which feed the Amazon River, presenting a significant water quality issue for Pucallpa and the Amazon basin as a whole. However, as mentioned previously, the required rate of oil changing will be reduced by as much as 2 million liters of motor oil per year (based on the conversion of 20,000 vehicles) after the conversion to LPG.

6.3 Assumptions Used For Calculating GHG Reductions

The following assumptions are used to determine the appropriate emission factors for each fuel type (leaded gasoline, unleaded gasoline, and LPG) and calculate total GHG emission reductions.

6.3.1 Vehicle Life

The project would continue to reduce greenhouse gas emissions for the length of time that the converted vehicles are on the road. If we assume that an average vehicle life is ten years beyond the time of conversion, then the project life would be ten years beyond the conversion of the last vehicle. Thus, if the vehicles are all converted during year one (2003), then the project life would be from 2003 to 2014 (2003 + 1 + 10 = 2014). Similarly, if the conversions take place over a four year period, the project life would be from 2003 to 2017 (2003 + 4 + 10 = 2017).

6.3.2 Vehicle efficiency

Testing performed by Aguaytia Energy using leaded gasoline and LPG mototaxis at unloaded highway conditions (38 km/hr) have resulted in the vehicle efficiencies shown in Table 6-4. Although testing has not been performed using unleaded gasoline, it is expected that the efficiency would be comparable to that of a leaded gasoline vehicle on a per-unit-of-energy basis.[79]

Much of the driving of the mototaxis will be done in loaded conditions with one to three passengers on board and in hilly city conditions, so the actual vehicle efficiencies would be lower. Efficiency data are not available for loaded conditions, however one can use the unloaded,

[79] Telephone conversation with Rich Bechtold, Independent Consultant, Colombia, MD; March, 2003.

highway mileage figures since it is only the relative differences that will affect the calculation. The calculation of vehicle efficiency on a per-Btu basis requires the knowledge of the fuel-specific energy content. For the calculation in Table 6-4, the fuel energy contents listed in Table 6-1 were assumed.

Table 6-4. Vehicle Efficiencies (Miles per gallon and miles per MMBtu)

Leaded Gasoline Vehicle	Unleaded Gasoline Vehicle	LPG Vehicle
51 MPG	--	57 MPG
432.9 miles/MMBtu	432.9 miles/MMBtu	596.1 miles/MMBtu
--	--	37.7% improvement

6.3.3 Emission Factors

In this case study we assume that the estimation of GHG emission reductions will be based on the project manager's fuel purchase records for the LPG vehicles. Thus, in addition to the amount of fuel purchased (in gallons of LPG) to run the LPG vehicles, we also need to calculate the emissions that would have taken place if a gasoline vehicle (both leaded and unleaded) had been used instead. In this subsection, the aim is to develop an emission factor for both the LPG "project" vehicle and the gasoline "baseline" vehicles. Each emission factor will be in terms of LPG-equivalent purchased by the project manager. The LPG purchased will be used to run the LPG vehicles, but its equivalent will also be used to calculate the amount of gasoline that would have been purchased to run the gasoline-powered vehicles. Therefore, all vehicle fuel types will use emission factors with units of grams of CO_2e per gallon of LPG-equivalent purchased.

The first step in deriving this per-gallon-LPG-equivalent emission factor is to determine the energy content of a gallon of LPG. In this case study, we will use the LPG energy content of 95,617 Btu per gallon, as reported by Aguaytia Energy. This number is based on laboratory testing of the LPG used in Peru, which contains 55 percent propane and 45 percent butane. However, since the LPG vehicle is 37.7 percent more efficient than gasoline vehicles on a miles-per-Btu basis, the gasoline vehicles will use more energy to travel the same distance by a factor of 37.7 percent, which is the ratio of LPG-to-gasoline efficiencies on a miles/Btu basis (see Figure 6-3).

The amount of energy used to travel a certain distance is then combined with the fuel-specific GHG emission factor. For this case study, we will use the IPCC-derived per-MMBtu GHG tailpipe emission factors for uncontrolled vehicles (see Chapter 3) and then use a correction factor to account for upstream emissions. These GHG tailpipe emission factors are presented in Table 6-5.

Table 6-5. IPCC-derived GHG Tailpipe Emission Factors (grams CO_2e/MMBtu)

Leaded Gasoline Vehicle	Unleaded Gasoline Vehicle	LPG Vehicle
77,475	77,475	67,233

Upstream Correction Factor. In the U.S., LPG refining is less GHG-intensive than gasoline refining. However, in many developing countries information on the energy-intensity of the fuel production processes is unavailable due to limited data collection and reporting infrastructure. Therefore, we use the fuel-independent tailpipe GHG-to-total GHG correction factor of 19 percent for unleaded gasoline and LPG (see Chapter 3). Since the production of leaded gasoline is generally less energy-intensive than unleaded gasoline, we further assume a 10 percent[80]

[80] Ibid.

improvement for upstream GHG emissions for leaded gasoline relative to unleaded gasoline. This yields a leaded gasoline correction factor of 17 percent. The different correction factors are listed in Table 6-6.

Table 6-6. Tailpipe GHG-to-Total Correction Factors to Account for Upstream Emissions

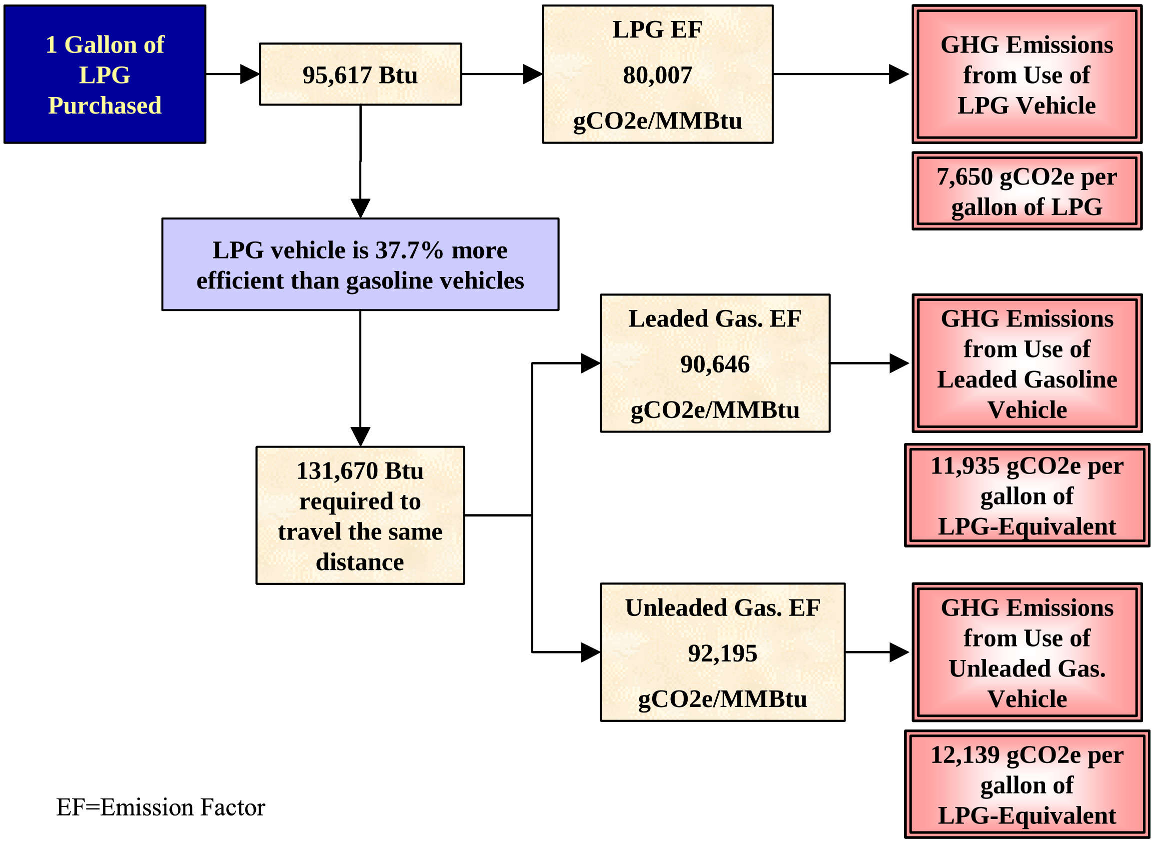
	LPG	Leaded Gasoline	Unleaded Gasoline
Tailpipe-to-Total GHG Emission Correction Factor	19%	19% - (10% of 19%) = 17%	19%
Total (Upstream and Tailpipe) GHG Emission Factors (grams CO_2e/MMBtu)	80,007	90,646	92,195

We can now combine the per-MMBtu emission factors with the vehicle fuel efficiencies to arrive at an emission factor that calculates GHG emissions for each vehicle fuel type based on the equivalent of one gallon of LPG purchased. The emissions for the gasoline vehicles are those emissions that would have taken place without the LPG-conversion project. These emission factors are listed in the second row of Table 6-7, and the entire calculation process is summarized in Table 6-3.

Table 6-7. Per-Gallon LPG-Equivalent Emission Factors

	LPG	Leaded Gasoline	Unleaded Gasoline
Total (Upstream and Tailpipe) GHG Emission Factors (grams CO_2e/MMBtu)	80,007	90,646	92,195
Total (Upstream and Tailpipe) GHG Emission Factors (grams CO_2e emitted / LPG-gallon-equivalent purchased)	7,650	11,935	12,139

Figure 6-3. GHG Emissions Associated with the Use of One Gallon of LPG



6.4 Project Baseline

The project baseline represents the GHG emissions that would have taken place in the absence of the project activity. If a vehicle is converted to LPG, what would it have used as fuel if it hadn't been converted and how would it have performed? For an individual vehicle, the answer will likely be that it would have continued to run on leaded gasoline until the ban on leaded gasoline entered into effect, after which is would have likely run on unleaded gasoline.

If it were the case that mototaxis in Pucallpa were to run on leaded gasoline, using the current engine technology and rate of maintenance for the foreseeable future, then the determination of baseline fuel emissions would be straightforward. It would consist of a static baseline of 11,935 grams of CO_2e per gallon of LPG-equivalent purchased.[81] However, the effects of a new law that will take effect in December 2005 and will phase out leaded gasoline over a 12-month period should be taken into consideration. As a result, we assume that a certain number of mototaxis will switch to unleaded gasoline after 2005, which will have an impact on the baseline GHG emission factor. In addition, the use of LPG is likely to increase as a result of the learning effects from the existing conversions of 1,700 mototaxis. We therefore assume that a "project" vehicle would replace some weighted average of a vehicle running on leaded gasoline, unleaded gasoline, and LPG. The relative weighting will depend on the forecast of the fuel markets, compliance with the ban on leaded gasoline, and other factors affecting how the individual mototaxi owners behave.

[81] Recall that all calculations are performed based on the amount of LPG-equivalent purchased by the project manager.

For the purposes of this study, the following three hypothetical baselines will be considered. The baselines are intended to represent the most likely future scenarios for the mototaxis market in the Pucallpa region. See Figure 6-4, for an illustration of these baselines.

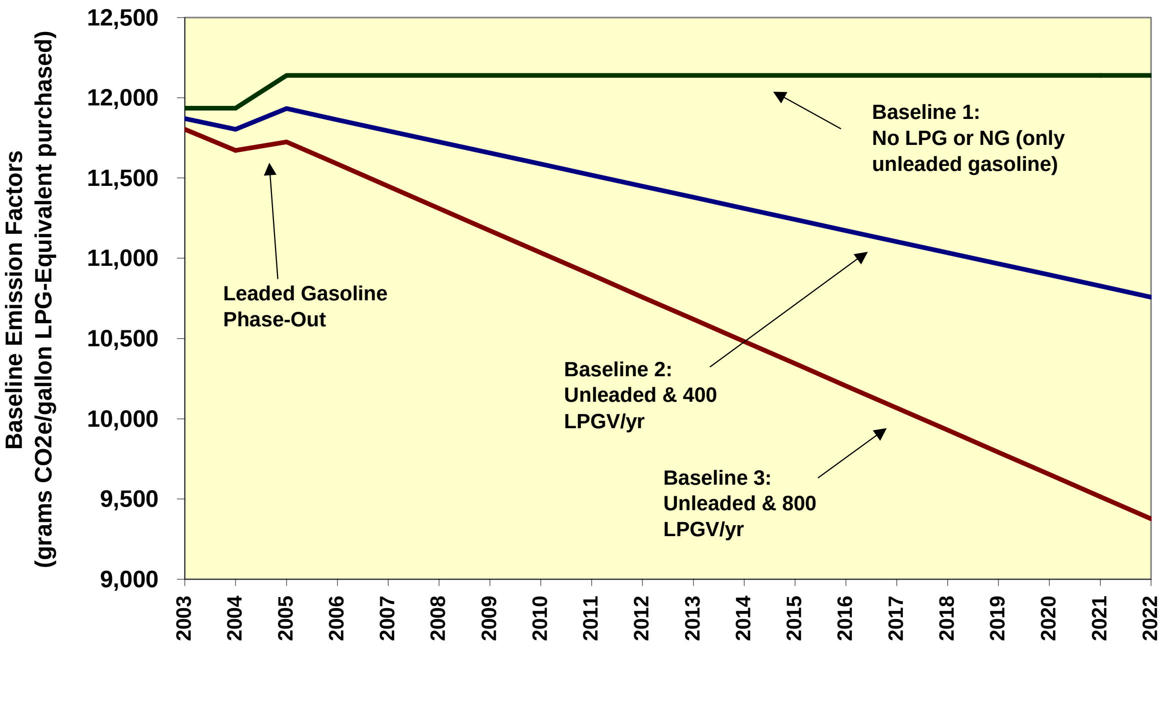
Baseline Scenario 1. Leaded gasoline is used until December of 2004, after which it is replaced by unleaded gasoline over a one year period. No non-project LPG is used.

Baseline Scenario 2. The second scenario builds on Baseline 1, but also takes into account increasing non-project LPG usage. Starting in year 2003, this scenario assumes that the market share of LPG vehicles will increase by 400 vehicles per year, or an annual increase of approximately 1.5 percent, out of the total market of 26,000 mototaxis[82] (400/26,000 = 1.54 percent of market share per year). For example, by 2007 (year five of the project), 2,000 LPG vehicles would be part of the baseline, which would now also include all unleaded gasoline, in compliance with the December 2004 date discussed above. Thus, 7.7 percent (2000/26,000) of the 2007 baseline would reflect the LPG emission factor of 7,650 grams per gallon of LPG equivalent, and the remaining 92.3 percent would reflect the unleaded gasoline emission factor of 12,139, calculated as follows:

$$[0.077 \times 7650] + [0.923 \times 12{,}139] = 11{,}793.35 \text{ grams } CO_2\text{e/gallon of LPG-equivalent}$$

Baseline Scenario 3. Same as Baseline 2, except the market share of LPG vehicles increase at a rate of 800 vehicles per year.

Figure 6-4. Baseline Options for the Mototaxi LPG Conversion Project



[82] Although the project is to convert 20,000 mototaxis to run on LPG, the total number of mototaxis currently operating in the region is 26,000, and therefore market share estimates are based on the 26,000 figure.

To calculate emission reductions, these baselines are compared with the emission rate of an LPG vehicle of 7,650 grams CO_2e per gallon LPG. This is illustrated in the Figure 6-5.

Figure 6-5. Annual Per-Gallon LPG-Equivalent GHG Reductions

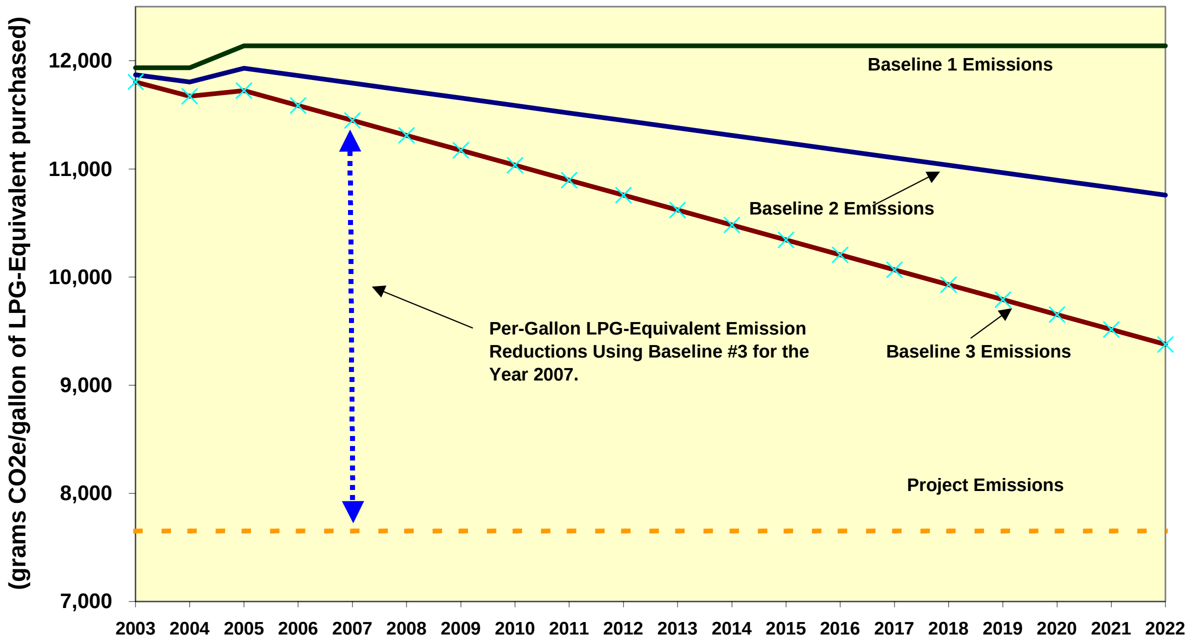


Table 6-8. Per-Gallon LPG-Equivalent Annual Emission Factors for Baseline and Project Scenarios (grams CO_2e/gallon LPG-Equivalent Purchased)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
BASE1	11,935	11,935	12,139	12,139	12,139	12,139	12,139	12,139	12,139	12,139
BASE2	11,869	11,804	11,932	11,863	11,794	11,725	11,656	11,587	11,518	11,449
BASE3	11,804	11,672	11,725	11,587	11,449	11,311	11,172	11,034	10,896	10,758
PROJECT	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
BASE1	12,139	12,139	12,139	12,139	12,139	12,139	12,139	12,139	12,139	12,139
BASE2	11,380	11,311	11,241	11,172	11,103	11,034	10,965	10,896	10,827	10,758
BASE3	10,620	10,482	10,344	10,205	10,067	9,929	9,791	9,653	9,515	9,377
PROJECT	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650

6.5 Additionality and Number of Eligible Vehicles

For the project to be eligible for participation in a GHG offset program, the project developers must demonstrate that the project would not have taken place in the absence of the financing and recognition provided by the GHG offset program; or at least that a certain part of the project (i.e. a fraction of the total number of vehicles) would not have taken place without the GHG offset program. In this section, we will evaluate the additionality of the case study and develop a few illustrative scenarios that quantify how many of the vehicle conversions may be considered additional. Only those vehicles that are considered additional will be included in the overall GHG reduction calculation.

For example, it may be that the project developers would have converted a certain number of vehicles for specific economic or strategic reasons, such as increasing the sale of LPG. However, these strategic reasons may not justify or ensure the conversion of *all* of the 20,000 vehicles considered as part of this effort. The remaining vehicle conversions that would not have been undertaken as part of such regular business practices would thus be considered additional and could be used to apply for carbon financing from a GHG offset program.

Another factor which should be considered in the context of additionality, is the *rate* at which the conversions would take place with and without the GHG-derived revenue. In some cases, it is possible that a number of conversions would take place in coming years as learning and LPG infrastructure increases, but that the potential for additional carbon financing would speed up this conversion process. In such cases, only those GHG emission reductions resulting from the increased rate of conversions should be counted as part of the GHG offset project, with the business-as-usual conversions excluded.

Ultimately, there will be a degree of latitude in interpreting the additionality requirement until a cannon of individual project precedents is developed over time. It will therefore be left to the project developer to justify and document its claims that a given project is, in fact, additional according to the spirit of the concept. For this case study we will examine four hypothetical project scenarios, which represent different degrees to which the vehicle conversions might have taken place in the absence of the project. The project developer will likely try to claim as many conversions to be additional as possible, but certain claims may be harder to justify and document than others. Thus each additionality scenario represents a varying number of additional vehicles and varying degree of ease in terms of justifying these claims. The different scenarios are meant to illustrate both how an additionality filter might work, and how the same project can generate different outcomes depending on the criteria used. Note that these scenarios are conservative given that none of them consider all 20,000 vehicles to be additional. The scenarios are summarized in Table 6-9 and Figure 6-7 below.

Additionality Scenario 1. No vehicle conversions are considered additional in this scenario. This would be the case if it is determined that it is in the financial or strategic interest of the project developer to subsidize all of the 20,000 vehicle conversions as fast as possible in order to obtain increased LPG market share. For example, Aguaytia Energy may decide that, as the only vendor of LPG in the area, the return on the US$240 investment for a single vehicle conversion would justify the expenditure of subsidizing the conversion of all 20,000 vehicles in order to out-compete vendors of gasoline in the area. In this case, all of the conversions would be undertaken as part of the business-as-usual scenario; they would not be considered additional and could therefore not be included in a GHG offset program.

Additionality Scenario 2. In this scenario, a subset of the total vehicle conversions is considered additional. If the project developer demonstrates that it is economically attractive to convert a certain number of vehicles, but that beyond this number the rate of return no longer justifies the expense without additional GHG revenue, then each vehicle beyond this point would be considered additional. For illustration purposes we will use a subset of 10,000 additional vehicles of the total 20,000 total vehicles to be converted. These conversions are assumed to take place at the project outset, and the vehicles are assumed to operate for 10 years after the conversion, at which point a new vehicle or engine would be purchased.

Additionality Scenario 3. This scenario also assumes that 10,000 vehicles will be considered additional. But, where Additionality Scenario 2 assumes that all of the vehicles are to be converted at the outset of the project (in year one), more realistically, these conversions would take place gradually over a 4 year period. This additionality scenario models the 4 year conversion period by assuming that 2,000 vehicles will be converted in the first year; 8,000 in year 2; 6,000 in year 3; and 4,000 in year 4, with half of these conversions being considered additional. Each vehicle is assumed to operate for 10 years after the conversion takes place.

Additionality Scenario 4. In this additionality scenario, it is assumed that all 20,000 vehicles will be converted slowly over the next decade, but that the potential for carbon financing will accelerate the conversion process significantly. Thus, only the emission reductions resulting from the difference in conversion rates would be considered additional. If the project developer demonstrates that it is economically justifiable to convert the vehicles at a rate of 2,000 per year, but that this rate can be increased to 5,000 per year over the next 4 years with the promise of GHG revenues, then those emission reductions that take place between the time of conversion and the point in time when the vehicle would have been converted anyway would be considered additional, as is illustrated in Figure 6-6.

Figure 6-6. Example of Rate-Based Additionality and Baseline Calculation, for Additionality Scenario 4

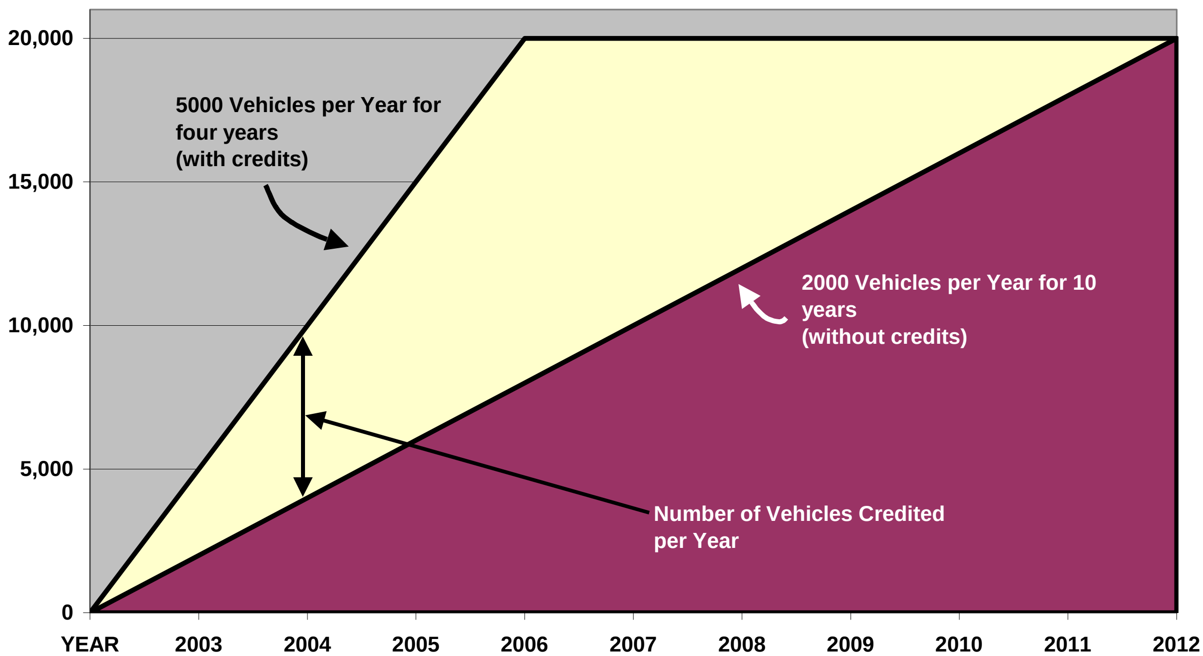
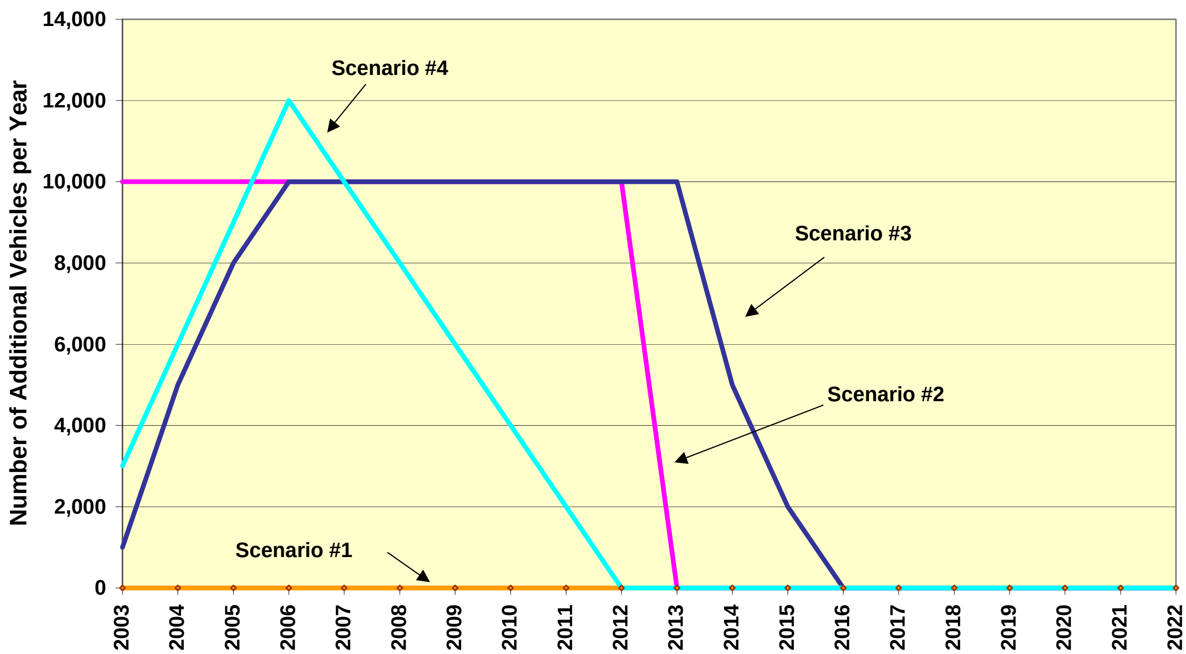


Table 6-9. Summary of the Four Additionality Scenarios (number of additional vehicles in each year)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ADD 1	-	-	-	-	-	-	-	-	-	-
ADD 2	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
ADD 3	1,000	5,000	8,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
ADD 4	3,000	6,000	9,000	12,000	10,000	8,000	6,000	4,000	2,000	-

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ADD 1	-	-	-	-	-	-	-	-	-	-
ADD 2	-	-	-	-	-	-	-	-	-	-
ADD 3	10,000	5,000	2,000	-	-	-	-	-	-	-
ADD 4	-	-	-	-	-	-	-	-	-	-

Figure 6-7. Summary of the Four Additionality Scenarios (number of additional vehicles in each year)



6.6 Net GHG Reductions Based on Fuel Purchase Records

Now that the number of vehicles to be considered additional and the per-gallon LPG-equivalent baselines have been quantified, the total GHG emission reductions can be calculated using the project manager's collected fuel purchase records. For the purposes of illustration, let us assume that the average volume of fuel purchased per LPG vehicle is 250 gallons per year for each year of the project life. In reality, the project manager would use the actual amount of fuel purchased. The 250 gallons of fuel corresponds to 14,250 miles traveled per year, which is consistent with Aguaytia Energy estimates. Equation A.1 describes the formula for calculating net GHG reductions in a given year based on the additionality and baseline scenarios chosen.

A.1	**Net GHG Emission Reductions in grams of CO_2e in year Y = [number of additional vehicles in year Y] x [Average Volume of Fuel Used by an LPG Vehicle in year Y] x [Baseline Emissions Factor for year Y – Project Emissions Factor for year Y]**

For example, in year 2007, using Additionality Scenario 4 (ADD4) and Baseline Scenario 3 (BASE3), the calculation is as follows:

A.2	**Net GHG Emission Reductions in grams of CO_2e in 2007 using ADD4 and B3 = [10,000 vehicles] x [250 gallons of LPG/vehicle] x [11,449 – 7,650 grams CO_2e/gallon-equivalent] = 9,497,500,000 grams = 9,497.5 metric tons CO_2e**

The calculation for the years 2003 to 2022 for ADD4 and BASE3 are summarized in Table 6-10.

Table 6-10. GHG Emission Reductions for Additionality Scenario 4 and Baseline Scenario 3 (metric tons of CO_2e)

YEAR	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
gallons LPG/year	250	250	250	250	250	250	250	250	250	250
ADD 4 (# of vehicles)	3,000	6,000	9,000	12,000	10,000	8,000	6,000	4,000	2,000	-
Baseline 3 EF (g/gal LPG)	11,804	11,672	11,725	11,587	11,449	11,311	11,172	11,034	10,896	10,758
Project EF (g/gal LPG)	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650
GHG Reductions (metric tons)	3,115	6,032	9,169	11,810	9,497	7,321	5,284	3,384	1,623	-

YEAR	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
gallons LPG/year	250	250	250	250	250	250	250	250	250	250
ADD 4 (# of vehicles)	-	-	-	-	-	-	-	-	-	-
Baseline 3 EF (g/gal LPG)	10,620	10,482	10,344	10,205	10,067	9,929	9,791	9,653	9,515	9,377
Project EF (g/gal LPG)	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650	7,650
GHG Reductions (metric tons)	-	-	-	-	-	-	-	-	-	-
									SUM	**57,235**

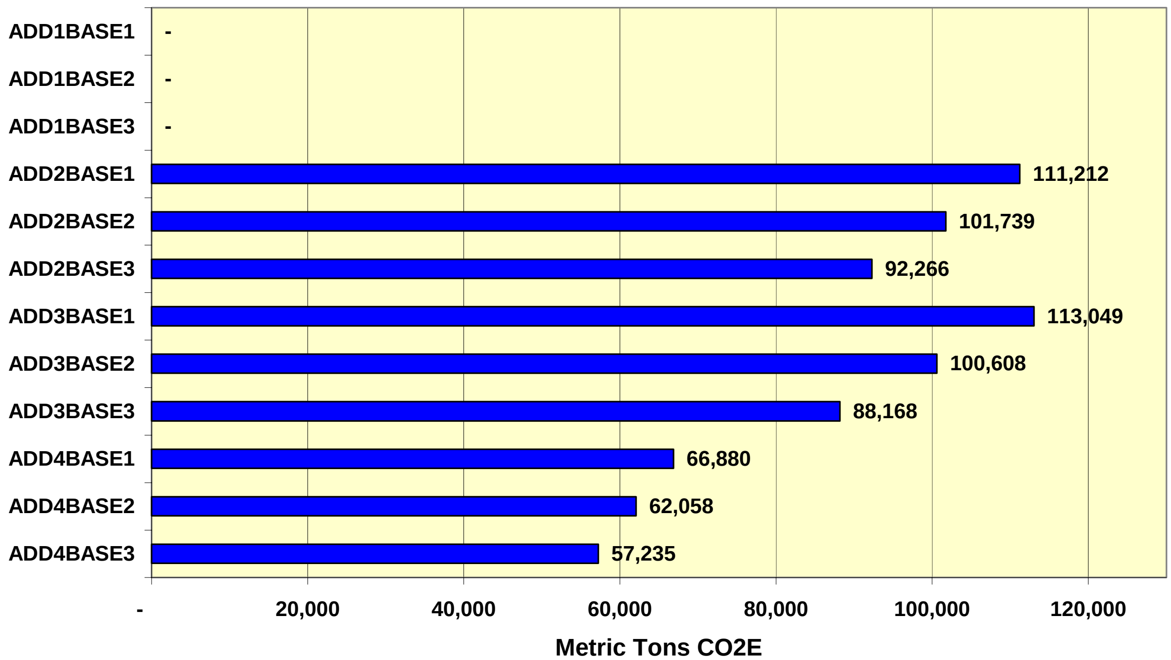
Note: EF = Emission Factor

Using this methodology, the potential GHG emission reductions were calculated for each of the baseline and additionality scenarios, assuming a steady average per-vehicle fuel consumption of 250 gallons of LPG-equivalent per year. In these calculations, each of the three baseline scenarios is combined with each of the four additionality scenarios, yielding a total of twelve potential outcomes with total lifetime reductions ranging from 57,000 to 113,000 metric tons of CO_2e. The results are summarized in Figure 6-8. This is a relatively small project compared to other GHG reduction programs that have been awarded financing. For comparison, the World Bank's Prototype Carbon Fund (PCF) has awarded financing to projects ranging from 141,000 to 3.5 million tons of CO_2e,[83] and the Dutch CERUPT program has accepted projects with reductions ranging from 100,000 to 5.4 million.[84] However, the Pucallpa project is on the right order of magnitude, and may be an attractive project option for a financing program or potential buyer, especially if that program or buyer is interested in gaining experience in the transportation sector.

[83] World Bank Prototype Carbon Fund. Second Annual Report. http://prototypecarbonfund.org/docs/2002AnnualReport.htm

[84] Senter International website. Contracted Projects. (May 12, 2003). http://www.senter.nl/asp/page.asp?alias=erupt&id=i001337. (May 12, 2003).

Figure 6-8. Total GHG Emission Reductions for Each Combination of Additionality and Baseline Scenario, 2003-2022 (metric tons CO_2e)



6.7 Potential Revenue From GHG Emission Reductions

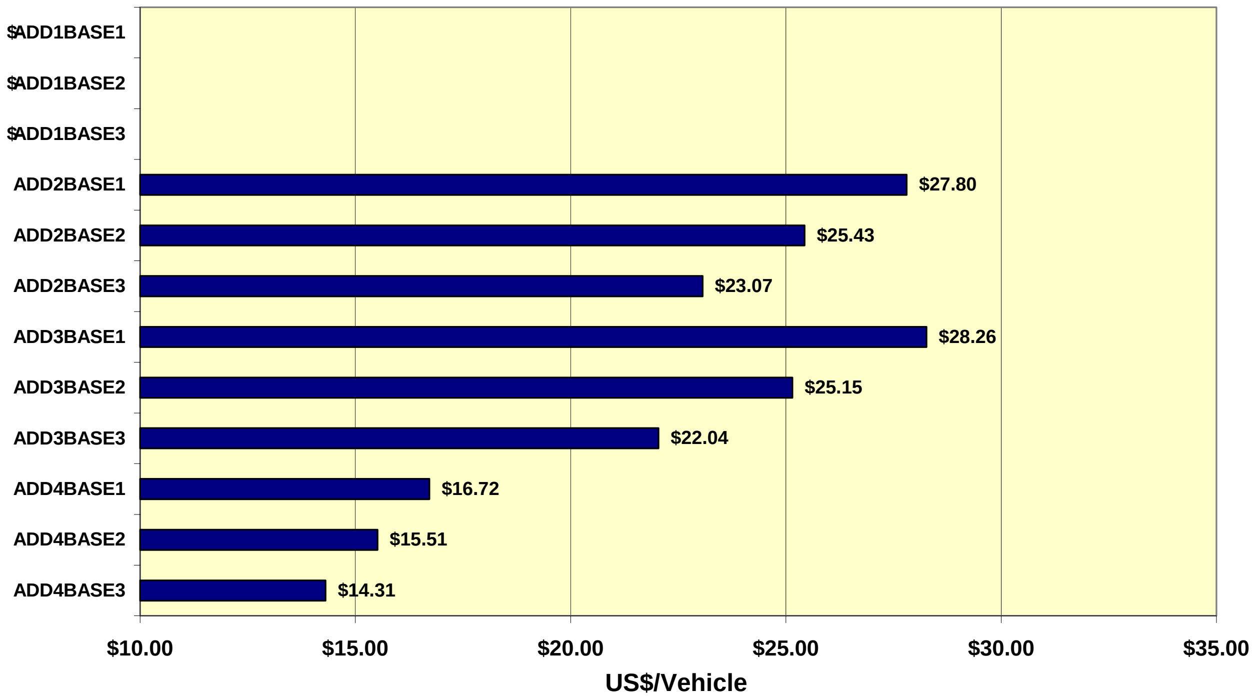
The GHG reductions calculated in the previous section and illustrated in Figure 6-8 fall in the range of 57,000 to 113,000 tons of CO_2e. Assuming a price of US$5/ton CO_2e for the sale of the GHG emission reductions,[85] the revenue generated for the entire project would be on the order of:

$$\$5 \text{ x } (57{,}000 \text{ to } 113{,}000 \text{ tons}) = \$285{,}000 \text{ to } \$565{,}000$$

This corresponds to the conversion of 20,000 vehicles, of which only a time-dependent fraction are considered additional. Thus the GHG revenue generated over the life of the project for each converted vehicle (whether additional or not) would be between $14.31 and $28.26, as illustrated in Figure 6-9.

[85] Please note that the price of $5 per ton CO_2e is hypothetical and does not represent a specific transaction or offer.

Figure 6-9. Per Vehicle GHG Revenue



Given that the total cost of conversion is $240, the GHG emission reductions amount to approximately 6 to 12 percent of the total cost of the LPG conversion. Likewise, given that the project developer is likely to subsidize about $180 of the conversion cost, the potential revenue from the emission reductions would represent 8 to 16 percent of the portion subsidized by the project developer. This is a significant percentage of the total cost and would provide real incentive for a developer in undertaking such a project.

6.8 Leakage

The above quantification of GHG emission reductions resulting from the conversion of gasoline mototaxis to LPG is based on the assumption that the use of LPG will not change the driving patterns of the individual taxi owners. If, however, the increased use of LPG led to an increase in miles driven or a change in fuel prices, then this would be a leakage effect and would need to be quantified. In the case of this mototaxi conversion project, it is unlikely that the use of LPG would have any affect on overall demand for mototaxi use, as the switch in fuels is unrelated to the demand for travel by taxi. Similarly, it is not envisioned that the fuel switch will result in a change in overall fuel prices significant enough to change the cost of individual taxi rides in a way that would significantly impact demand for mototaxi use.

6.9 Case Study Conclusions

In this chapter, the general process for quantifying GHG emissions and emission reductions resulting from LPG vehicle projects was applied to a case study using data from current LPG conversions of mototaxis in Pucallpa, Peru. By developing a number of baseline and additionality scenarios, we were able to determine a range which yields an order of magnitude estimation of the potential GHG reductions resulting from such a project and the potential revenue such a project might represent. Converting 20,000 LPG vehicles yields a net reduction over the ten to twenty year project lifetime of between 57,000 and 113,000 tons of CO_2e. This is based on a relatively conservative set of assumptions with regard to additionality and emission factors, and the case could certainly be made for less conservative inputs which would yield greater overall reductions. As it stands, the Pecullpa project represents a economically and technically viable GHG project that could likely attract carbon financing. The main barrier in moving forward would not be the size or cost of the reductions over the project lifetime, but the ability of the developer to transparently document that the claimed reductions are real and verifiable, according to specific requirements of the potential program or buyer in question.

Because the case study is still hypothetical and there is little available guidance on estimating GHG emission benefits from transportation projects, the GHG estimates provided in this case study should only be used to illustrate methods for determining GHG emissions benefits. To proceed further and actually submit the project to a specific GHG registry or offset program, the project developer would need to choose the scenario that most accurately reflects the situation of that specific project, develop an appropriate emission baseline that reflects this scenario, and then justify and document the chosen scenario. This documentation should take into account the application criteria of any potential buyer of the GHG offsets to ensure that the calculated reductions will be acceptable.

Appendices

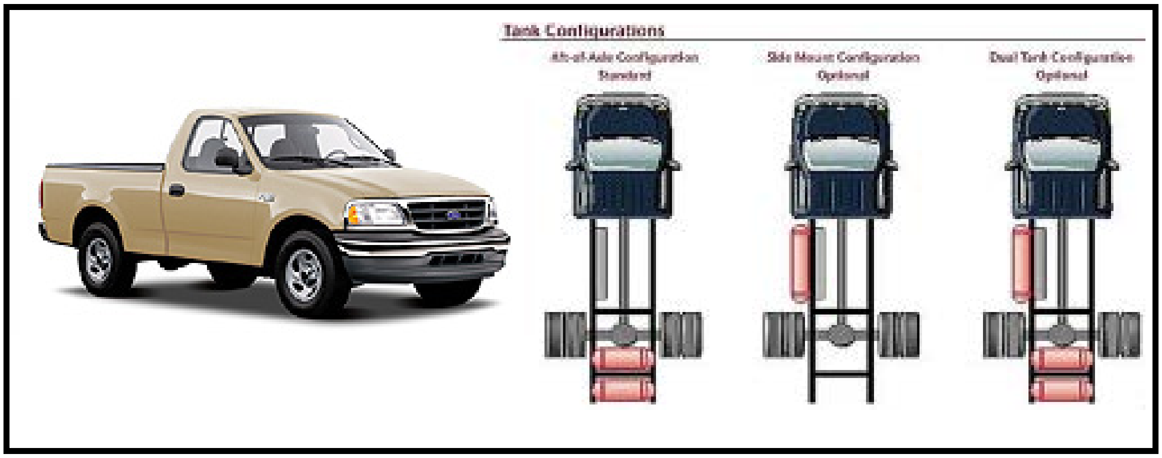
A1. Comparison of LPG Vehicles to Similar Performance Gasoline-Powered Vehicles

This appendix shows three comparisons that illustrate the different performance achieved with either gasoline or LPG in dedicated, bi-fuel, and converted vehicle models. The three vehicle model comparisons are: 1) the Ford F150 Bi-fuel LPG Pickup; 2) the Volvo S40 gasoline-dedicated model and bi-fuel (gasoline - LPG) model; and 3) the MG Rover 45 dedicated gasoline model and converted LPG model. In all three comparisons, the fuel economy of LPG is lower, however it is often offset by lower fuel cost; the GHG emissions are lower when bi-fuel and converted vehicles are fueled on LPG; and a small loss of vehicle and engine performance is measured.

In the first comparison, the Ford F150 Bi-fuel LPG Pickup truck is tested for performance when fueled by gasoline and LPG and then compared to a gasoline-only model. Ford offers several different bi-fuel models, and produces more bi-fuel LPF pickup trucks than any other alternative fuel vehicle original equipment manufacturer (OEM). In this case, while both trucks have 5.4-liter 8-valve engines, there is a small loss in performance of power output (12-percent) and torque (7-percent) with the bi-fuel engine when compared to the gasoline-only model. (Chart A1)

Chart A1 also shows detailed data comparing fuel economy and greenhouse gas emissions resulting from the gasoline engine and operation of the bi-fuel engine fueled by gasoline or LPG. When comparing fuel economy, the gasoline engine rates higher than the bi-fuel run on both fuels. Also, the bi-fuel finds improved consumption during highway driving when fueled by gasoline. In this case, GHG emissions are presented as metric tons of CO_2 equivalent emitted per year. When LPG fuels the bi-fuel vehicle, there is a 5-percent decrease in GHG emissions; however, this is still 15 percent higher than the gasoline-only model.[86] The Ford F150 Bi-fuel qualifies for a ULEV rating (described further in Appendix 4) under U.S. EPAct standards.

Chart A1. Ford F-150 Gasoline and Bi-fuel Pickup Trucks



[86] Greenhouse gas emissions are estimated by the U.S. Department of Energy, GREET Model, Argonne National Laboratory

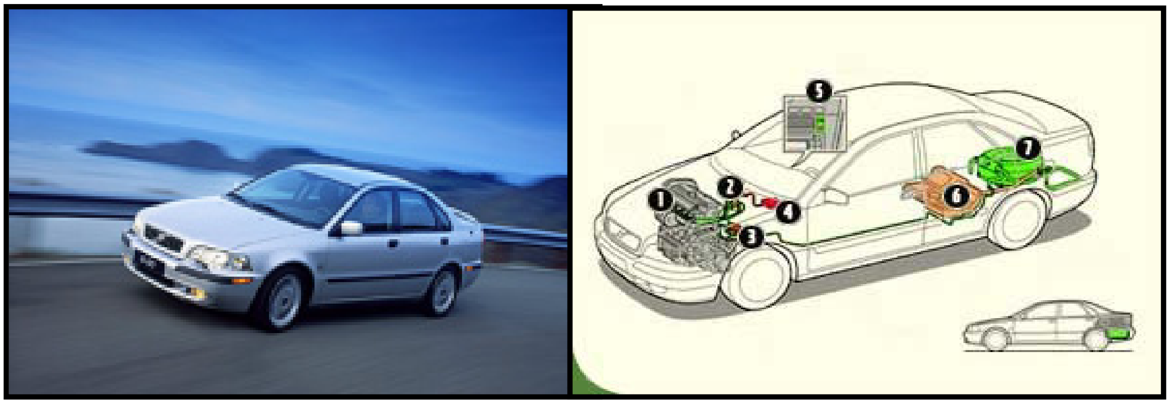
FORD F150 GASOLINE ENGINE	FORD F150 BI-FUEL ENGINE on GASOLINE	FORD F150 BI-FUEL ENGINE on LPG
Engine Specifications Engine type: 5.4L gasoline V8 Transmission: automatic, 2WD	**Engine Specifications** Engine type: 5.4L bi-fuel LPG V8 Transmission: automatic, 2WD	**Engine Specifications** Engine type: 5.4L bi-fuel LPG V8 Transmission: automatic, 2WD
Performance Power output: 260 horsepower @ 4500 rpm Torque: 350 feet/pounds @ 2500 rpm Fuel consumption (city / highway): 15 mpg / 19 mpg Greenhouse Gas Emissions: 11.5 metric tons/year[1]	**Performance** Power output: 230 horsepower @ 4500 rpm Torque: 325 feet/pounds @ 2500 rpm Fuel consumption (city / highway): 12 mpg / 16 mpg Greenhouse Gas Emissions: 13.9 metric tons/year[1]	**Performance** Power output: 230 horsepower @ 4500 rpm Torque: 325 feet/pounds @ 2500 rpm Fuel consumption (city / highway): 12 mpg / 13 mpg Greenhouse Gas Emissions: 13.2 metric tons/ year[1]

[1] Emissions are presented in metric tons of CO_2 equivalent emitted per year. Estimates include the full fuel cycle and exclude vehicle manufacture. Estimates are based on 45-percent highway driving, 55-percent city driving, and 15,000 annual miles. See website http://www.fueleconomy.gov.
Source: The Ford Motor Company web site: http://www.fleet.ford.com

In the second comparison, the Volvo S40 is shown offered with a gasoline engine and bi-fuel engine. Volvo bi-fuel cars have double fuel systems and two tanks - one for LPG and one for the back-up fuel (in this case gasoline). The engine always starts on gasoline, but when it is in LPG mode the engine will automatically switch to LPG shortly after start. Should the car run out of LPG, the engine will automatically switch over to gasoline.

Chart A2 compares the performance of this vehicle with both fuel-type engines, and running on both gasoline and LPG. The vehicle performance of acceleration and top speed is nearly identical between the engines and fuels. While the fuel consumption of the bi-fuel engine running on LPG is lower (27.2 mile per gallon as compared with 34.9 mpg on gasoline and 36.2 mile per gallon for the dedicated gasoline engine), the lower fuel cost of LPG (per gallon equivalent) can offset this lower mile per gallon rating. The CO_2 emissions of the bi-fuel engine running on LPG are about 13 percent lower than either the same engine running on gasoline or the gasoline-dedicated engine.

Chart A2. Volvo S40 Petrol and Bi-Fuel Models



VOLVO S40 1.8 GASOLINE ENGINE	VOLVO S40 1.8 BI-FUEL on GASOLINE	VOLVO S40 1.8 BI-FUEL on LPG
Engine Specifications	**Engine Specifications**	**Engine Specifications**
Engine type: Four-cylinder gasoline-dedicated engine	Engine type: Four-cylinder Bi-Fuel LPG/ gasoline engine	Engine type: Four-cylinder Bi-Fuel LPG/ gasoline engine
Transmission: manual	Transmission: manual	Transmission: manual
Displacement: 1783 cc	Displacement: 1783 cc	Displacement: 1783 cc
Power output: 90 kW (122 bhp) at 5800 rpm	Power output: 90 kW (122 bhp) at 5800 rpm	Power output: 88 kW (120 bhp) at 5800 rpm
Torque: 174 Nm at 3750 rpm	Torque: 170 Nm at 4000 rpm	Torque: 167 Nm at 4000 rpm
Performance	**Performance**	**Performance**
Acceleration 0-62 mph: 10.5 seconds	Acceleration 0-62 mph: 10.5 seconds	Acceleration 0-62 mph: 11 seconds
Top speed: 124 mph	Top speed: 124 mph	Top speed: 124 mph
Range on full tank (60 liters): 769 km	Range on full tank: 741 km	Range on full tank: 394 km
Fuel consumption, Combined driving (city and highway): 36.2 mpg	Fuel consumption, Combined driving (city and highway): 34.9 mpg	Fuel consumption, Combined driving (city and highway): 27.2 mpg
CO_2 Emissions: 187 g/km	CO_2 Emissions: 193 g/km	CO_2 Emissions: 168 g/km
Price (base retail): 14,835 pounds[1]	**Price (base retail):** 16,635 pounds	**Price (base retail):** 16,635 pounds

Notes: (1) LPG injectors; (2) Gas distributor; (3) Pressure regulator; (4) Engine Control Unit; (5) LPG/Gasoline switch; (6) Gasoline tank; and (7) LPG Tank under boot floor.
[1] Prices provided by Volvo are in British pounds. Near the time of publication of this manual, currency exchange rates convert these prices to approximately US$23,251 (gasoline engine) and US$26,072 (bi-fuel engine).
Source: Volvo Bi-Fuel web site: http://vcc.volvocars.se/bifuel/

Finally, we examine the MG Rover 45 model, which is offered with a gasoline engine and an OEM-approved converted LPG engine. MG Rover, in partnership with EcoGas Systems Ltd. and Landi Renzo, has developed unique aftermarket-fit LPG conversions approved for Rover vehicles. Initially, the conversions produced for MG Rover will be available for manual cars powered by the 1.8 liter engine. Extending the availability of LPG conversions to more MG Rover products is being studied.

Chart A3 compares the performance of this vehicle with the two engines. In practical terms, with LPG offering a lower heat value than average unleaded (95RON octane) gasoline, vehicle performance such as maximum speed, acceleration, power, and torque are all slightly lower, generally by about 5 percent.[87] While fuel consumption for LPG is lower (measured in miles per gallon), it is still often more cost effective, for example in Great Britain where LPG is currently half the price of gasoline. CO_2 emissions are 8 percent lower in the converted LPG vehicle than in the gasoline model, qualifying for a U.S. EPAct ULEV or EU4 rating.

Chart A3. MG Rover 45 Petrol Engine and LPG Conversion

MG ROVER 45 **Engine Specifications** Engine Type: 1.8 Liter, 4-cylinder, 16 volt Displacement: 1796 cc Transmission: manual	
PETROL ENGINE **Performance** Fuel consumption, Combined driving (city and highway): 38.9 mpg CO_2 Emissions: 173 g/km Vehicle Price: From 9,995 pounds[1]	**CONVERTED LPG ENGINE** **Performance** Fuel consumption, Combined driving (city and highway): 28.7 mpg CO_2 Emissions: 159.9 g/km Conversion Price: 2,195 pounds[1]

[1] Prices provided by MG Rover are in British pounds. Near the time of publication of this manual, currency exchange rates convert these prices to approximately US$15,492 (vehicle price) and US$3,402 (conversion price).
Source: EcoGas Systems Ltd.

[87] Personal communication with representative(s) from MG Rover Group Ltd, Sales & Marketing Centre.

A2. U.S. State Registries for Reporting of GHGs and State Legislation and Policies to Promote GHG Emission Reductions

GHG registries are designed to publicly record and provide public recognition for the GHG emission reduction efforts of an entity (e.g. company, household, individual). Registries also provide tools to assist these entities in quantifying and recording their efforts to reduce GHG emissions. Registries can also help raise awareness of climate change, promote sharing of lessons learned and success stories, and publicize low-cost mitigation opportunities.

This appendix provides a summary of recent actions and legislation taken by states, counties, and regional associations towards developing GHG registries. In addition to the actions taken at the state level, the Department of Energy's 1605(b) Voluntary Reporting of Greenhouse Gases Program is being revised and strengthened to provide verifiable and transferable credit for emission reduction activities under a potential future emission reduction scheme. On February 14, 2002, President Bush introduced the Administration's official policy on climate change:

> Our immediate goal is to reduce America's greenhouse gas emissions relative to the size of our economy. […] Our government will also move forward immediately to create world-class standards for measuring and registering emission reductions. And we will give transferable credits to companies that can show real emission reductions.[88]

The President's Global Climate Change Policy Book specifically addresses local and national GHG registries:

> The President directed the Secretary of Energy, in consultation with the Secretary of Commerce, the Secretary of Agriculture, and the Administrator of the Environmental Protection Agency, to propose improvements to the current voluntary emission reduction registration program under Section 1605(b) of the 1992 Energy Policy Act within 120 days… A number of proposals to reform the existing registry — or create a new registry — have appeared in energy and/or climate policy bills introduced in the past year. The Administration will fully explore the extent to which the existing authority under the Energy Policy Act is adequate to achieve these reforms.[89]

Many states are reacting to the Administration's policy and are eager to provide comments during the 1605(b) enhancement process. Project developers should keep abreast of current events with respect to these emerging registry programs.[90]

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[88] White House Office of the Press Secretary, "President Announces Clear Skies & Global Climate Change Initiatives," 14February 2002, <http://www.whitehouse.gov/news/releases/2002/02/20020214-5.html> (12 May 2003).

[89] White House, Global Climate Change Policy Book, February 2002, <http://www.whitehouse.gov/news/releases/2002/02/climatechange.html> (12 May 2003).

[90] Interested parties can check http://www.pi.energy.gov/enhancingGHGregistry/index.html for updates from the DOE's Policy Office, which is charged with spearheading the 1605(b) enhancement process.

Table A1 U.S. State Registries for Reporting of Greenhouse Gases and State Legislation/Policies to Promote GHG Emission Reductions

Region/State /City	Directive	Date	Objective	Contact
California	Senate Bill 1771	Signed September 30, 2000	Specified the creation of the non-profit organization, the California Climate Action Registry (California Registry). The California Registry will help various California entities to establish GHG emissions baselines. Also, the California Registry will enable participating entities to voluntarily record their annual GHG emissions inventories. In turn, the State of California will use its best efforts to ensure that organizations that voluntarily inventory their emissions receive appropriate consideration under any future international, federal, or state regulatory regimes relating to GHG emissions.[91]	Pierre duVair, Ph.D. Program Manager, California Energy Commission Climate Change tel: 916-653-8685 email: pduvair@energy.state.ca.us
	Assembly Bill 1493	Signed July 22, 2002	Assembly Bill 1493 is the first law in the U.S. to reduce GHG emissions from cars and light trucks, and provides an opportunity for automobile manufacturers to take advantage of incentives for early action. The law will regulate GHG emissions in 2009, and encourages earlier reductions from motor vehicles through the California Registry.	Pierre duVair, Ph.D. Program Manager, California Energy Commission Climate Change tel. 916-653-8685 email: pduvair@energy.state.ca.us
Illinois	Senate Bill 372[92]	Signed September, 2001[93]	This bill requires the Illinois EPA to establish an interstate nitrogen oxide trading program and issue findings that address the need to control or reduce emissions from fossil fuel-fired electric generating plants. The findings are to address the establishment of a banking system, consistent with DOE's Voluntary Reporting of Greenhouse Gases Program for certifying credits for voluntary offsets of emissions of greenhouse gases, or reductions of GHGs.[94]	Steven King Illinois Environmental Protection Agency tel: 217-524-4792 email: steven.king@epa.state.il.us
Maine	Legislative Document 87[95]	Passed April 6, 2001	This Document requires the Maine Department of Environmental Protection to develop rules to create a voluntary registry of GHG emissions. The rules must provide for the collection of data on the origin of the carbon emissions as either fossil fuel or renewable resources, and the collection of data on production activity to allow	Robert Daigle (bill sponsor) tel: (800) 423-2900; e-mail: rdaigle@gwi.net; or

[91] California Energy Commission, Global Climate Change & California, <http://www.energy.ca.gov/global_climate_change/index.html> (12 May 2003).

[92]Full text of Illinois Senate Bill 372 can be read at website, <http://www.legis.state.il.us/scripts/imstran.exe?LIBSINCWSB372> (cannot find updated link).

[93]Illinois State Senate Democrat News, 9 September 2001, http://www.senatedem.state.il.us/senatenews/news.shtml.
Illinois State Senate Democrat News, 9 September 2001.

[94] U.S. Environmental Protection Agency, Legislative Initiatives, <http://yosemite.epa.gov/globalwarming/ghg.nsf/actions/LegislativeInitiatives> (12 May 2003).

[95] Full text of Maine Legislative Document 87 can be read at website, <http://janus.state.me.us/legis/bills/.

Region/State /City	Directive	Date	Objective	Contact
			the tracking of future emission trends.	Maine Department of Environmental Protection tel: 800-452-1942
Massachusetts	Department of Environmental Protection Regulation 310 CMR 7.29	Issued April 23, 2001	This requires the six highest-polluting power plants in Massachusetts to meet overall emission limits for nitrogen oxide and sulfur dioxide by October 1, 2004 and begin immediate monitoring and reporting of mercury emissions. For the six affected plants, the rule caps total carbon dioxide emissions and creates an emission standard of 1,800 lbs. of carbon dioxide per megawatt-hour (a reduction of 10 percent below the current average emissions rate). The carbon dioxide limits must be met by October 1, 2006 or October 1, 2008 for plant retrofit or replacement. Plant operators may meet the standard either by increasing efficiency at the plant, or by purchasing credits from other reduction programs approved by the Department of Environmental Protection.[96]	MA Department of Environmental Protection InfoLine, tel: 617-338-2255 or 800-462-0444 email: dep.infoline@state.ma.us or for Emissions Trading: Bill Lamkin, tel: 978-661-7657 email: Bill.Lamkin@state.ma.us or Nancy Seidman Air Program Planning Unit tel: 617-556-1020 email: Nancy.Seidman@state.ma.us
New England Governors / Eastern Canadian Premiers	Climate Change Action Plan[97]	Signed August, 2001	The Climate Change Action Plan defines incremental goals for the coalition: in the short-term, reduce regional GHG emissions to 1990 emissions by 2010; for the mid-term, reduce regional GHG emissions by at least 10 percent below 1990 emissions by 2020, and establish an iterative five-year process, beginning in 2005, to adjust existing goals, if necessary, and set future emissions reduction goals; and for the long-term, reduce regional GHG emissions sufficiently to eliminate any dangerous threat to climate; current science suggests this will require reductions of 75 percent-85 percent below current levels. The action plan calls for the creation of a regional emissions registry and the exploration of a trading mechanism.	New England Secretariat New England Governors' Conference Inc. tel: 617-423-6900 email: negc@tiac.net

[96] U.S. Environmental Protection Agency, Legislative Initiatives, <http://yosemite.epa.gov/globalwarming/ghg.nsf/actions/LegislativeInitiatives> (12 May 2003).

[97] Full text of the New England Governors / Eastern Canadian Premiers Climate Change Action Plan can be read at http://www.cmp.ca/CCAPe.pdf.

Region/State /City	Directive	Date	Objective	Contact
New Hampshire	House Bill 284, "Clean Power Act"	Approved January 2, 2002	This four-pollutant bill is the first in the nation to include carbon dioxide.[98] Emission reduction requirements include 75% of sulfur dioxide by 2006; 70% of nitrogen oxide by 2006; 3% of carbon dioxide by 2006 (1990 levels); and mercury levels are still to be determined by 2004.[99] The cap and trade program maintains its own electronic measuring system separate from the NH GHG Registry (see below).	New Hampshire Office of the Governor tel: 603-271-2121
	Senate Bill 159 (and New Hampshire Code of Administrative Rules, Chapter Env-A 3800)	Approved July 6, 1999	This bill established a registry for voluntary GHG emission reductions to create an incentive for voluntary emission reductions.[100] The registry is intended to allow participants to quantify and submit GHG emission reduction actions to a state database for safekeeping against some future federal action. The New Hampshire Dept. of Environmental Services would support recognition and protection of such reductions under any federal program. Implementation rules were adopted on February 23, 2001. The registry includes reporting of project-based transportation activities	Joanna Morin Department of Environmental Science tel: 800-498-6868 or 603-271-1370 email: jmorin@desstate.nh.us
New York State	Greenhouse Gas Task Force	Created June, 2001	Governor Pataki set up a Greenhouse Gas Task Force to come up with policy recommendations on climate change.[101] Preliminary recommendations for actions and policies from the Task Force's Working Groups include establishing a statewide target for GHG emission reductions relative to 1990 levels, and establishing a greenhouse registry to document baseline emissions and voluntary emission reductions for participating customers.	Governor's website: http://www.state.ny.us/governor
	Assembly Bill 5577	Introduced February 27, 2001	This bill provides for regulation of emissions of nitrogen oxide, sulfur dioxide and carbon dioxide. This bill passed the Assembly on March 25, 2002, and has been referred in the Senate to the Environmental Conservation Committee.[102]	Richard Brodsky bill sponsor tel: 518-455-5753 or 914-345-0432 email: brodskr@assembly.state.ny.us
Suffolk County, NY	Carbon Dioxide Law, Res. No. 2286-2000	Passed July 24, 2001	Suffolk County became the first county to pass a resolution limiting carbon dioxide emissions. The resolution seeks to encourage efficiency in existing power plants and future facilities by setting allowable rates for carbon dioxide emissions and penalties for exceeding those limits. Under the law taking affect March 1, 2002,	Suffolk County Executive's Office tel: 631-853-4000

[98] New Hampshire, Office of the Governor, Press Releases, "Governor Shaheen Hails House Passage of Clean Power Act," http://www.state.nh.us/governor/media/010202clean.html.

[99] Brian M. Jones, "Emerging State and Regional GHG Emission Trading Drivers," presented at the Electric Utilities Environmental Conference, Tuscan, Arizona, January 2002.

[100] New Hampshire, Senate Bill 0159, http://www.gencourt.state.nh.us/legislation/1999/sb0159 (link no longer active).

[101] Press Release, Office of the Governor of New York State, June 10, 2001, http://www.state.ny.us/governor/press/year01/june10_01.html.

[102] New York State Assembly, Bill 5577, http://www.assembly.state.ny.us/leg/?bn=A.5577.

Region/State /City	Directive	Date	Objective	Contact
			any power plant in the county that generates over 1,800 pounds of carbon dioxide emissions per Megawatt/hour would be fined two dollars for every ton above the limit. An additional $1 per excess ton would be charged in each consecutive year. The bill contains several alternatives to paying fines, including buying emission credits through nationally recognized carbon dioxide trading markets, investing in alternative energy sources or donating penalties to community environmental groups.[103] There are currently 11 companies subject to the multi-pollutant regulations.	
Northeast States for Coordinated Air Use Management (NESCAUM)	NESCAUM GHG Emissions Trading Demonstration Project (Legislation N/A)	Early 1990s	The New England States (addressed above under "New England Governors/Eastern Canadian Premiers) along with New York and New Jersey have created an interstate association of air quality control divisions, titled the Northeast States for Coordinated Air Use Management (NESCAUM). NESCAUM supports the States, businesses, and environmental groups in the region with their development of registries, provides other technical assistance, and facilitates information exchange. This project looks at the effects and protocols of several other programs, such as 1605(b) and the New Hampshire Voluntary Registry. NESCAUM is also considering developing a GHG registry for all its member states.	Timothy Roskelley NESCAUM tel: 617-367-8540 email: tjroskelley@nescaum.org
Oregon	House Bill 3283	Signed June 26, 1997	This bill established a carbon dioxide standard requiring new utilities to emit 17% less than the most energy efficient plant available.[104] The bill capped carbon dioxide emissions at 0.7 pounds of carbon dioxide per kilowatt-hour for base-load natural gas-fired power plants; in 1999 the cap was lowered to 0.675 pounds per kilowatt-hour. New energy facilities built in the state must avoid, sequester, or pay a per-ton of carbon dioxide offset into the Oregon Climate Trust.[105] The nonprofit Oregon Climate Trust is a public benefit corporation that was established to facilitate the development and implementation of offset projects mandated under the state's carbon dioxide standard. The Trust accepts mitigation funds from energy facilities for displacing their unmet emissions requirements, and in turn must use the funds to carry out projects that avoid, sequester, or displace the carbon dioxide. The Trust accepts transportation projects and has already approved one commuter project.	For more information on purchasing carbon dioxide offsets in Oregon, or applying for project funding for new carbon dioxide mitigation projects, contact Mike Burnett Executive Director, Climate Trust tel: 503-238-1915 email: info@climatetrust.org website: http://www.climatetrust.org

[103] Suffolk County, Press Release, "Suffolk Becomes First County to Limit CO2 Emissions," July 24, 2001, http://www.co.suffolk.ny.us/exec/press/2001/emissions.html.
[104] Full text of Oregon House Bill 3283 can be read at http://www.leg.state.or.us/97reg/measures/hb3200.dir/hb3283.int.html.
[105] U.S. Environmental Protection Agency, Legislative Initiatives, http://yosemite.epa.gov/globalwarming/ghg.nsf/actions/LegislativeInitiatives.

Region/State /City	Directive	Date	Objective	Contact
Texas	Texas Natural Resources Conservation Commission, report on greenhouse gases and recommendations from the Executive Director	Draft Presented January 18, 2002	In August 2000, the Texas Natural Resources Conservation Commission (TNRCC) issued a decision instructing the agency's Executive Director to prepare a report on GHGs. The draft recommendations included "Develop and maintain a voluntary registry for reporting GHG emission reductions resulting from specific emission reduction or sequestration projects and energy efficiency improvements within Texas.* [*The Chairman directed staff, before executing this recommendation, to evaluate the DOE 1605(b) voluntary greenhouse gas registry program, as is or with some changes, as a possible element of a Texas GHG registry which avoids duplicative reporting.]"[106]	Office of Environmental Policy, Analysis and Assessment tel: 512-239-4900 email: policy@tnrcc.state.tx.us
Washington (Seattle)	City of Seattle Resolution Numbers 30316 and 30359	Both resolutions adopted July 23, 2001	Resolution 30316 calls for completion of an inventory of GHG emissions from 1990 and 2000 to be completed by the Office of Sustainability and Environment and commits the city to achieving GHG emission reductions from 7% below 1990 levels to 40% below 1990 levels by 2010. Resolution 30359 outlines Seattle City Light's (Seattle's municipal electric utility) strategy for meeting the goal of zero net emissions and establishing specific GHG mitigation targets and timelines. To begin meeting these requirements, Seattle City Light issued a RFP for GHG offset projects in November 2002. This initial RFP for offset projects is intended to offset the Utility's GHG emissions for 2003 and 2004.	Doug Howell Seattle City Light tel: 206-684-3853 email: doug.howell@seattle.gov
Wisconsin	Assembly Bill 627	February 8, 2000	This bill requires the Wisconsin Department of Natural Resources to establish and operate a system for registering reductions in emissions of GHGs if the reductions are made before they are required by law. [107]	Wisconsin Voluntary Emission reductions Registry Advisory Committee http://www.dnr.state.wi.us/org/aw/air/hot/climchgcom/

[106] Texas Natural Resource Conservation Commission, Office of Environmental Policy, Analysis and Assessment, "Overview and Recommendations Identified by A Report to the Commission on Greenhouse Gases," February 8, 2002, http://www.tnrcc.state.tx.us/oprd/sips/greenhouse/.

[107] Full text of Wisconsin Assembly Bill 627 can be read at http://www.legis.state.wi.us/1999/data/AB627.pdf.

Region/State /City	Directive	Date	Objective	Contact
	Wisconsin Emission Reduction Registry Rule, Chapter NR 437, Wis. Adm. Code	N/A	A rule (NR 437) is proposed to establish voluntary emissions reduction registries for GHGs, as well as for mercury, fine particulate matter and other contaminants that cause air pollution. The rule represents a new Department of Natural Resources policy to systematically record and track voluntary emission reductions by industries, electric utility companies, agricultural and forestry interests, and transportation and energy efficiency interests. NR 437 establishes the rules and procedures under which the new registry will operate. The rule also identifies the sources that are eligible to register reductions for GHGs like carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorcarbons and sulfur hexafluoride, as well as for nitrogen oxides, sulfur dioxide, volatile organic compounds, carbon monoxide, mercury, lead and fine particulate matter. Transportation activities are covered by this registry.	Eric Mosher tel: 608-266-3010 e-mail Eric.Mosher@dnr.state.wi.us

A3. 2001 LPG-Fueled Vehicle Projects Reported to the 1605(b) U.S. Voluntary Reporting of Greenhouse Gases Program

Table A3. 2001 LPG Fuel Vehicle Projects Reported to the U.S. Voluntary Reporting of Greenhouse Gases Program with Reductions Reported for the Most Recent Reporting Year[108]

(Project Description and Estimation Method are quoted directly from the Reporters' EIA-1605(b) reports)

Reporting Entity	Project Name	Alternative Fuel / Project Size	Reported CO_2 Equivalent Reduction (Metric tons)
Cinergy Corporation			
Fleet Alternative Fuels		Natural Gas and LPG / 131 Vehicles	Direct: 108.6
Project Description	The Cinergy Corporation operates a certain number of its vehicles using the alternative fuels LPG and natural gas. The company has one LPG filling station and currently has three natural gas filling stations (two open to the public). The natural gas vehicles are dual fuel vehicles - natural gas and gasoline. This is due to the fact that compressed natural gas is used and has a limited volume, which limits vehicle range. LPG is used in passenger vehicles, light trucks, and heavy trucks. Compressed natural gas is used in passenger vehicles and light trucks. The company has an aggressive program to provide technical assistance and compressor equipment to other fleet operators, and has opened a commercial conversion facility for the general public. Emissions reported for this project are emissions for the entire vehicle fleet, based on motor gasoline, diesel, LPG and natural gas consumption.		
Estimation Method	The following were the emission rates used, all from 1605(b) Instructions, Appendix B: 19.641 lb CO_2/gal gasoline 12.669 lb CO_2/gal LPG 120.593 lb CO_2/Mcf natural gas		
Exelon Corporation			
Alternative Fuel Vehicles - ComEd Fleet		Liquefied Petroleum Gases/LPG, Ethanol / 351 Vehicles	Direct: 351.3 Indirect: 136.0

[108] **All Data are for the year 2000 unless otherwise indicated.**

Reporting Entity	Project Name	Alternative Fuel / Project Size	Reported CO_2 Equivalent Reduction (Metric tons)
Project Description	In 1999, Commonwealth Edison invested in 82 Dodge Neons that were converted to run on LPG, 9 Ford F 150s that run on LPG and 16 flex-fuel Ford Rangers that run on 85% ethanol and 15% gasoline. In 1999 these vehicles were used for a total of 444,392 miles. In 2000, ComEdison invested in 128 flex-fuel vehicles (85% ethanol and 15% gasoline) - 43 GMC Sonomas, 26 Ford Rangers (6 cycle), and 59 Ford Rangers (4 Cycle). Also in 2000, ComEdison vehicles utilizing LPG totaled 122 vehicles - 98 cars and 23 LD trucks and 1 caravan. Collectively these vehicles were used for a total of 979,300 miles. In 2001, ComEdison vehicles utilizing LPG totaled 110 vehicles and vehicles utilizing E-85 totaled 241 vehicles. Collectively these vehicles were used for a total of 3,896,813 miles. Other fuel (ZZ) reported in Fuel Switching (Part II, Q. 5) is ethanol (E-85).		
Estimation Method	The method ComEd used to calculate emissions and reductions combines both direct emissions (tailpipe) and indirect emissions (upstream emissions resulting from extraction processing, delivery and storage) into one lump-sum number. Since the EIA 1605(b) database differentiates between the two we separate them into these respective categories (direct and indirect). The below equation represents the combined emissions from direct and indirect sources Emission reductions were calculated from: Annual Emissions = Annual Mileage*FM + Annual Fuel Use*Ff Where: FM = emissions factor per mile driven (from EIA Guidelines) Ff = emissions factor per unit of fuel used (from EIA Guidelines) In order to separate direct and indirect one can use an alternative method to calculate direct emissions alone and then subtract this number from the total found using the above equation. The difference represents indirect emissions. We first multiplied the amount of alternative fuel E-85 and LPG a the ComEd fleet consumed by the emissions coefficient for CO_2 that can be found in Volume II, Part 4 Transportation Sector of the DOE Sector Specific Issues and Reporting Methodologies Supporting the General Guidelines for the Voluntary Reporting of GHGs under 1605(b).		
TXU			
	Alternative Fuel Vehicle Program	LPG / Unknown	0
Project Description	TXU`s fleet of alternatively fueled vehicles are capable of operating on gasoline or LPG. In 2001, these vehicles were driven using mostly gasoline and the Company did not track miles for the two types of fuel used. Therefore, we are not taking credit for the use of alternative fuels in 2001.		
Estimation Method	Estimates of the reduction of carbon dioxide from operating alternative fueled vehicles were based on the assumption that equivalent miles would have been driven by gasoline powered vehicles. First, the equivalent tons of carbon dioxide from gasoline vehicles were calculated then this quantity was subtracted from the equivalent tons of carbon dioxide generated from alternative fueled vehicles driving the same number of miles. Emission factors for carbon dioxide per fuel type were taken from Tables 4.2 and 4.3, page 4.19 of the Sector-Specific Issues and Reporting Methodologies, Volume II, part 4- Transportation Sector, October 1994. The DOT CAFE Standard of 27.5 mpg divided by 1.15 was used as the miles per gallon of gasoline and 20 mpg divided by 1.15 for LPG was estimated.		

Reporting Entity	Project Name	Alternative Fuel / Project Size	Reported CO_2 Equivalent Reduction (Metric tons)
	The emission factors used for this project are listed:		

	Direct	Indirect	Total
Gasoline	8,900	2,100	11,000 g/gal
LPG	5,747	483	6,230 g/gal
Methane	60.5	3.9	64.4 g/ft3

A4. Regulatory and Policy Frameworks Promoting LPG Vehicles

Numerous regulatory policies have been introduced in the U.S. and abroad to promote the use of LPG vehicles and facilitate the development of LPG vehicle along with a range of other AFVs.[109] Many of these policies are intended to help improve urban air quality and reduce dependence on fossil fuels, and some offer the indirect added benefit of reducing GHG emissions. This appendix considers a number of relevant regulations, policies, and programs that encourage the adoption of LPG vehicles, as well as the development and implementation of new LPG vehicle technologies that can be used in LPG vehicle projects. The appendix provides an overview of the following: (1) federal laws and regulations affecting LPG vehicles; (2) state initiatives; (3) voluntary programs and support activities promoting LPG vehicles; and (4) international climate change programs.

A4.1 Federal Laws and Regulations

The Energy Policy Act of 1992 (EPAct) introduced several of the most relevant elements of Federal policy promoting the development and use of alternative fuels in the transportation sector.[110] The primary motivations behind promoting alternative fuels under EPAct include reducing the nation's dependence on foreign oil and increasing the nation's energy security through the use of domestically produced alternative fuels.[111] To do so, EPAct established a goal of replacing 10 percent of petroleum-based motor fuels in the United States by the year 2000 and 30 percent by the year 2010. The statute also adopted the goal of seeking to reduce air, water, and other environmental impacts—including emissions of greenhouse gases—that result from the combustion of fossil fuel through transportation and other energy-consuming activities.[112] As discussed below, EPAct provides two principal instruments that promote the use of LPG vehicles: first, provide tax credits and deductions for the purchase of AFVs and development of AFV infrastructure, and second, mandate that Federal, State, and private "alternative fuel provider" fleets must purchase AFVs.[113]

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[109] The term "alternative fueled vehicle" is defined as any dedicated vehicle or a dual-fueled vehicle. (Energy Policy Act of 1992) As provided in EPAct, the term "alternative fuel" is defined as:

> methanol, denatured ethanol, and other alcohols; mixtures containing 85 percent or more (or such other percentage, but not less than 70 percent, as determined by the Secretary, by rule, to provide for requirements relating to cold start, safety, or vehicle functions) by volume of methanol, denatured ethanol, and other alcohols with gasoline or other fuels; natural gas; liquefied petroleum gas; hydrogen; coal-derived liquid fuels; fuels (other than alcohol) derived from biological materials; electricity (including electricity from solar energy); and any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits.

[110] Energy Policy Act of 1992, Public Law 102-486.

[111] EPAct §2001.

[112] Ibid.

[113] According to the U.S. Department of Energy, an "alternative fuel provider" is defined as [an entity] that owns, operates, leases, or otherwise controls 50 or more light-duty vehicles (LDVs) in the U.S. that are not on the list of EPAct Excluded Vehicles [such as emergency or law enforcement vehicles], at least 20 of those LDVs are used primarily within a Metropolitan Statistical Area (MSA)/Consolidated Metropolitan Statistical Area (CMSA), and those same 20 LDVs are centrally fueled or capable of being centrally fueled. LDVs are centrally fueled if they capable of being refueled at least 75% of the time at a location that is owned, operated, or controlled by any fleet, or under contract with that fleet for refueling purposes. An alternative fuel provider is covered under EPAct if its principal business involves one of the following: producing, storing, refining, processing, transporting, distributing, importing, or selling any alternative fuel (other than electricity) at wholesale or retail; generating, transmitting, importing, or selling electricity at wholesale or retail; or if it produces and/or imports an average of 50,000 barrels per day or more of

A4.1.1 Federal Tax Incentives for LPG Vehicles

EPAct provides two forms of tax incentives that promote AFVs: (1) a Federal tax deduction available to individuals and businesses purchasing qualified clean-fuel vehicles; and (2) a Federal tax deduction for business expenses related to the incremental cost of purchasing or converting to qualified clean-fuel vehicles.

Clean Fuel Vehicle Deduction

Title XIX of EPAct amended the Internal Revenue Code to provide tax deductions for the purchase of clean-fuel vehicles and certain refueling property, or for the conversion of a vehicle into one using clean-burning fuel.[114] Under those provisions, a qualified clean-fuel vehicle is one that operates using a "clean-burning fuel" such as liquefied petroleum gas (LPG) among other alternative fuels.[115] Individuals or businesses will receive a Federal income tax deduction of between $2,000 and $50,000 per vehicle for the incremental cost to purchase or convert gasoline-powered vehicles into LPG vehicles and other qualified clean-fuel vehicles—and a deduction of up to $100,000 for certain kinds of property used for refueling these vehicles (see Table A4-1).[116]

These deductions are available for clean-fuel vehicles put into service between December 20, 1993 and December 31, 2004.[117] After an introductory period for the deduction that ended in 2001, the deduction amount is reduced by 25 percent of the original amount each year, and will be phased out completely by 2005. The tax deduction for clean-fuel vehicles is available for any applicable business or personal vehicle, except for certain electric vehicles that are eligible for a separate tax credit under related provisions. The deduction is not amortized and must be taken in the year the vehicle is acquired.[118]

As described in Table A4-1, the maximum tax deduction for trucks or vans with gross vehicle weight of between 10,000 and 26,000 pounds is $5,000 per vehicle. The maximum deduction is $50,000 per vehicle for trucks and vans over 26,000 pounds, or buses with seating capacity of 20 or more adults. Other clean-fuel vehicles may qualify for up to a $2,000 deduction. Table A4-1 also details the maximum deductions for vehicles put into service after 2001 and through 2004, the final year the deduction may be taken before it is fully phased out.

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petroleum, and 30% or more of its gross annual revenues are derived from producing alternative fuels. http://www.ott.doe.gov/epact/alt_fuel_prov.shtml.

[114] See Internal Revenue Code, 26 U.S.C. §179A. See also EPAct, Title XIX, Subtitle A - Energy Conservation 7 [sic] Production Incentives. See also IRS Publication 535 (2001), page 44.

[115] 26 U.S.C. §179A(e). Clean-burning fuels include natural gas, liquefied natural gas, liquefied petroleum gas, hydrogen, electricity, and any other fuel at least 85 percent of which is one or more of the following: methanol, ethanol, any other alcohol, or ether. Id.

[116] 26 U.S.C. §179A(c).

[117] 26 U.S.C. §179A(g).

[118] U.S. Department of Energy, "Alternative Fuel Vehicle Fleet Buyer's Guide," http://www.fleets.doe.gov/cgi-bin/fleet/main.cgi?17357,state_ins_rep,5,468050; see also IRS Publication 535 (U.S. Department of Energy, 2001), page 44.

Table A4-1. Summary of Deductions for Clean-Fuel Vehicles

Date Vehicle Acquired	Vehicle Type	Deduction Available
Dec. 20, 1993-2001	truck or van with GVW 10,000-26,000 lbs.	$5,000
	truck or van with GVW over 26,000 lbs.	$50,000
	each bus, with seating capacity of at least 20 adults (excluding driver)	$50,000
	all other vehicles (excluding off-road vehicles)	$2,000
2002	truck or van with GVW 10,000-26,000 lbs.	$3,750
	truck or van with GVW over 26,000 lbs.	$37,500
	each bus, with seating capacity of at least 20 adults (excluding driver)	$37,500
	all other vehicles (excluding off-road vehicles)	$1,500
2003	truck or van with GVW 10,000-26,000 lbs.	$2,500
	truck or van with GVW over 26,000 lbs.	$25,000
	each bus, with seating capacity of at least 20 adults (excluding the driver)	$25,000
	all other vehicles (excluding off-road vehicles)	$1,000
2004	truck or van with GVW 10,000-26,000 lbs.	$1,250
	truck or van with GVW over 26,000 lbs.	$12,500
	each bus, with seating capacity of at least 20 adults (excluding the driver)	$12,500
	all other vehicles (excluding off-road vehicles)	$500
2005	Deduction fully phased out for all vehicles	None

Source: 26 U.S.C. §§179A(b)-179A(c).

Deduction for Qualified Clean-Fuel Vehicle Refueling Property

Qualified clean-fuel vehicle refueling property is defined as property that is used "for the storage or dispensing of a clean-burning fuel" for use in a qualified clean-fuel vehicle.[119] The tax deduction available for such refueling property for each location where it is put into service is up to $100,000, minus the total deductions on all such property placed in service at the location in all earlier years.[120] The deduction for the property is not reduced in value over time, as it is for the qualified clean-fuel vehicles, but the deduction will end starting in 2005.[121]

A4.1.2 AFV Acquisition Requirements for Federal, State, and Alternative Fuel Provider Fleets

In addition to providing tax incentives for AFVs, EPAct created new AFV procurement mandates for Federal, state, and "alternative fuel provider" fleets to purchase AFVs. EPAct first introduced

[119] 26 U.S.C. §179A(d).
[120] See IRS Publication 535 (2001), page 46.
[121] For more information, contact Winston Douglas, Alternative Fuels Tax Provisions, at (202) 622-3110, fax (202) 622-4779; or Frank Boland, Alcohol Fuel Tax Information, at (202) 622-3130; or call the toll-free order desk at (800) 829-3676. U.S. Department of Energy, "Alternative Fuel Vehicle Fleet Buyer's Guide" http://www.fleets.doe.gov/cgi-bin/fleet/main.cgi?17357,state_ins_rep,5,468050.

AFV acquisition requirements in Federal fleets, and these provisions have been underscored by several Executive Orders that further the commitments of Federal agency fleets to adopt AFVs. Likewise, state and alternative fuel provider fleets must meet the requirements outlined in the Alternative Fuel Transportation Program, Final Rule, under the EPAct implementing regulations.[122] At the time of publication of this report, the U.S. Department of Energy, in implementing EPAct, is considering whether to also extend EPAct's AFV procurement requirements to local government and private fleets, authorized under EPAct Sections 507(g) and 507(k).[123] AFV purchasing requirements for Federal agencies, states, alternative fuel providers, local governments, and private entities are discussed in what follows.[124]

EPAct Procurement Requirements for AFVs in Federal Fleets

Section 303 of EPAct required the entire Federal government, under the direction of the Department of Energy, to acquire at least 5,000 light-duty AFVs in FY1993, 7,500 light-duty AFVs in FY1994, and 10,000 light-duty AFVs in FY1995. Following FY1995, all Federal fleets consisting of at least 20 or more light-duty motor vehicles operating in a "metropolitan statistical area"[125] must meet a specific percentage requirement for AFVs. As summarized in Table A4-2 below, these requirements include 25 percent in FY1996, 33 percent in FY1997, 50 percent in FY1998, and 75 percent in FY1999 and thereafter.[126] (See "Success of the EPAct AFV Program for Federal Fleets" later in this section.)

Table A4-2. Summary of EPAct Requirements for Federal Government Acquisition of AFVs

Fiscal Year Vehicle Acquired	Applicable Fleet	Number of AFVs Required
FY1993	Entire Federal Government	5,000 total light-duty AFVs
FY1994		7,500 total light-duty AFVs
FY1995		10,000 total light-duty AFVs
FY1996	Each Federal fleet with 20 or more light-duty vehicles in a "metropolitan statistical area"	20% of each fleet as AFVs
FY1997		33% of each fleet as AFVs
FY1998		50% of each fleet as AFVs
FY1999 and thereafter		75% of each fleet as AFVs

Table A4-3 summarizes the annual purchase requirements for Federal and State fleets, alternate fuel providers, and private and municipal fleets. Each of these fleets is described in the sections that follow.

[122] 10 CFR Part 490.
[123] See http://www.ott.doe.gov/epact/private_fleets.shtml.
[124] Additional information about the U.S. Department of Energy's AFV programs under EPAct, see http://www.ott.doe.gov/epact.
[125] EPAct §303 defines a "metropolitan statistical area" as having a population of 250,000 or more in 1980 according to the U.S. Census. This definition is not always consistent with other provisions of EPAct.
[126] EPAct §303.

Table A4-3. Summary of AFV Purchase Requirements under EPAct

Model Year	Federal	State	AFV Provider	Private Fleets
1997	33%	10%	30%	0
1998	50%	15%	50%	0
1999	75%	25%	70%	0
2000	75%	50%	90%	0
2001	75%	75%	90%	0
2002	75%	75%	90%	20%
2003	75%	75%	90%	40%
2004	75%	75%	90%	60%
2005 and later	75%	75%	90%	70%

Source: DOE, Office of Transportation Technologies, "EPACT/Clean Fuel Fleet Program Fact Sheet," http://www.afdc.doe.gov/pdfs/caaa.pdf.

To encourage and promote the use of AFVs in Federal fleets, EPAct also created an incentive program and a recognition and incentive awards program for Federal agencies. Under the Act, the General Services Administration (GSA) may offer a reduction in fees charged to agencies to lease AFVs below those fees charged for the lease of comparable conventionally-fueled motor vehicles.[127] The GSA is also required to establish an annual awards program that recognizes Federal employees who have demonstrated "the strongest commitment to the use of alternative fuels and fuel conservation in Federal motor vehicles."[128] Moreover, the Act required the U.S. Postal Service to provide a report to Congress outlining its AFV program.[129]

Executive Order 13149: Fuel Economy and AFV Procurement Requirements for Federal Fleets

Federal agencies have been required to follow guidelines established by several Executive Orders, starting with Executive Order 12844 (April 21, 1993) and Executive Order 13031 (December 13, 1996), both of which underscored the policies and objectives of the Federal agency AFV provisions of EPAct. Both of those Orders were superceded by Executive Order 13149, signed in April 21, 2000, which further strengthened the Federal government's commitment to promote the use of all types of AFVs in Federal fleets.

Executive Order (E.O.) 13149 requires Federal agencies operating 20 or more motor vehicles within the United States to reduce the fleet's annual petroleum consumption by 20 percent below FY1999 levels by the end of FY2005.[130] Federal agencies are given significant flexibility in developing an appropriate strategy to meet the petroleum reduction levels. Agencies are required to use alternative fuels, such as LPG, to meet the majority of the fuel requirements for vehicle fleets operating in "metropolitan statistical areas," defined in E.O. 13149 as metropolitan areas with populations of more than 250,000 in 1995 according to the Census Bureau. Where feasible, the Order also instructs agencies to consider procuring "innovative" alternative fuel vehicles—such as LPG vehicles—that are capable of large improvements in fuel economy. Agencies are required to increase the average EPA fuel economy rating of their light-duty vehicle acquisitions by at least one mile per gallon (mpg) by 2002 and 3 mpg by 2005 above 1999 acquisition levels. Agencies are also encouraged to adopt awards and performance evaluation programs that

[127] EPAct §306.
[128] EPAct §307.
[129] EPAct §311.
[130] E.O. 13149 §201. Independent agencies are encouraged but not required to comply with the Order. E.O. 13149 §504.

reward federal employees for exceptional performance in implementing the Order.[131] Federal fleet requirements under E.O. 13149 are summarized in Table A4-4.

Table A4-4. Summary of E.O. 13149 Requirements for Federal Fleets

Applicable Fleet	Action Required	Compliance Deadline
Each Federal fleet with 20 or more light-duty vehicles	Increase average EPA fuel economy rating of light-duty vehicle acquisitions by 1 mpg above FY1999 levels	FY2002
	Increase average EPA fuel economy rating of light-duty vehicle acquisitions by 3 mpg above FY1999 levels	FY2005
	Reduce fleet's annual petroleum consumption by 20% below FY1999 levels	By end of FY2005
Each Federal fleet with 20 or more light-duty vehicles operating in metropolitan statistical areas	Same action as above, but must include alternative fuels to meet majority of fuel requirements	By end of FY2005

E.O. 13149 also establishes an AFV acquisition credit program for Federal agencies pursuant to the requirements under EPAct. In preparing an annual report to DOE and the Office of Management and Budget (OMB), each Federal agency acquisition of a light-duty AFV counts as one credit towards fulfilling EPAct's AFV acquisition requirements. Agencies receive one additional credit for each light-duty AFV that exclusively uses an alternative fuel, and for each zero emission vehicle. Agencies receive three credits for dedicated medium-duty AFVs and four credits for dedicated heavy-duty AFVs.[132] Table A4-5 summarizes the number of credits available for each type of acquired AFV.

Table A4-5. Summary of Credits for Federal Fleet Acquisitions of AFVs under Executive Order 13149

Type of AFV	Number of Credits Awarded
Each light-duty AFV	1 credit
Each light-duty AFV exclusively using an alternative fuel	2 credits
Each ZEV	2 credits
Each dedicated medium-duty AFV	3 credits
Each dedicated heavy-duty AFV	4 credits

Fleet owners may use these credits to meet acquisition requirements in later years or to sell and trade credits with other fleets. Thus, fleet owners that do not meet the E.O. acquisition requirements for AFVs may purchase credits from fleet owners with a surplus of AFVs credits.

In order to provide for adequate access to refueling infrastructure, Federal agencies are directed under E.O. 13149 to "team with state, local, and private entities to support the expansion and use

[131] E.O. 13149 §303
[132] E.O. 13149 §401.

of" public refueling stations for AFVs.[133] State, local, and private groups may also establish non-public alternative fuel stations if no commercial infrastructure is available in their territory.[134]

Success of the EPAct AFV Program for Federal Fleets

According to the Department of Energy (DOE) Clean Cities Report *Federal Fleet AFV Program Status,* dated June 2, 1998, as of 1998, of more than 570,000 vehicle acquisitions overall, the estimated cumulative total AFV acquisitions in Federal agencies totaled more than 34,000 vehicles between FY1991 and FY1998. This represented about 80 percent compliance with the 44,600 required AFV acquisitions under EPAct. Of those AFVs acquired by 1998, several hundred were LPG vehicles.[135]

As a result of the missed target for Federal AFV acquisitions under EPAct, in January 2002 three environmental organizations filed a lawsuit in Federal court against 17 Federal agencies for failing to comply with EPAct.[136] The plaintiffs claim that all 17 agencies have failed: (1) to meet their AFV acquisition requirements; (2) to file the necessary compliance reports with Congress; and (3) to make these reports available to the public. The complaint also alleges that DOE failed to complete a required private and municipal AFV fleet rulemaking. As a remedy, the plaintiffs requested that the court order the agencies to comply with these requirements, and require the agencies to offset their future vehicle purchases with the number of AFVs necessary to bring them into compliance with EPAct's acquisition requirements for 1996 through 2001.

In July 2002, a California federal court ruled in favor of the plaintiffs finding that the agencies failed to meet EPAct AFV acquisition requirements. However, the court did not order the agencies to comply with the mandates or offset future AFV purchases, noting that it was the Secretary of Energy's responsibility to deal with non-compliance issues. With regard to compliance reports, the court found that the agencies failed to meet reporting requirements and laid out a schedule for the agencies to file overdue reports. The court ordered the agencies to prepare the reports by November 26, 2002 and post them on the Internet by January 31, 2003.[137] As for the complaint that DOE failed to complete private and municipal AFV fleet rulemaking, the court found that DOE had failed to meet this requirement and ordered compliance. A hearing on this matter occurred in September 2002 with the court ordering DOE to publish a proposed rule by the end of January 2003 and a final rule by the end of November 2003. The rule is to address three issues: (1) whether EPAct's goal of reducing petroleum usage by 30% by 2010 is feasible or whether it

[133] E.O. 13149 §402(a).
[134] E.O. 13149 §402(b).
[135] U.S. Department of Energy, Federal Fleet AFV Program Status (June 2, 1998), available at: http://www.ccities.doe.gov/pdfs/slezak.pdf. As stated in the report:

> Of the 34,000+ AFVs acquired by Federal agencies, approximately 10,000 (30 percent) have been M-85 (methanol mixed with gasoline) flexible fuel vehicles, 6,000 (17 percent) have been E-85 (ethanol mixed with gasoline) flexible fuel vehicles, and 18,000 (52 percent) have been compressed natural gas (CNG) vehicles. Several hundred each of electric and liquefied petroleum gas (LPG or LPG) vehicles have also been acquired. Projections for future Federal AFV acquisitions, based on discussions with Federal agencies' procurement personnel and manufacturers, indicate that flexible fuel E-85 vehicles will be the most common AFV procured by agencies' to comply with EPACT, followed by CNG.

[136] Center for Biological Diversity v. Abraham, N.D. Cal., No. CV-00027 (January 2, 2002). The agencies named in the suit are the Departments of Energy, Commerce, Justice, Interior, Veterans Affairs, Agriculture, Transportation, Health and Human Services, Housing and Urban Development, Labor, State, and Treasury; the Environmental Protection Agency; the U.S. Postal Service; the National Aeronautics and Space Administration; the U.S. Nuclear Regulatory Commission; and the General Services Administration.
[137] See http://www.evaa.org/evaa/pages/fedreb_court_rules_epact_.html.

should be revised, (2) whether a private and municipal fleet mandate is necessary to meet the goal, and (3) whether the goal will actually be met if the mandate is enforced[138]

EPAct Procurement Requirements and Incentives for AFVs in Alternative Fuel Provider and State Fleets

In 1996, DOE issued final regulations that spell out fleet responsibilities under the State and Alternative Fuel Provider Program. Like the Federal fleet requirements, this is a DOE regulatory program that requires covered state and "alternative fuel provider" fleets to purchase AFVs as a portion of their annual light-duty vehicle acquisitions.[139]

As with Federal fleets, EPAct requires alternative fuel providers to acquire AFVs as a portion of their annual light-duty acquisitions, starting with Model Year (MY) 1996.[140] The implementing regulations under EPAct Chapter 501 provide a schedule for *alternative fuel providers* to acquire light-duty AFVs as follows: 30 percent for model year 1997; 50 percent for model year 1998; 70 percent for model year 1999; and 90 percent for model year 2000 and thereafter.[141] (See Table A4-6.)

Table A4-6. EPAct Requirements for Light-Duty AFV Acquisitions for Alternative Fuel Providers

Model Year Vehicle Acquired	Percentage of AFVs Required
MY1997	30 percent
MY1998	50 percent
MY1999	70 percent
MY2000 and thereafter	90 percent

The AFV regulations cover a state agency if it owns or operates 50 or more light-duty vehicles, at least 20 of which are used primarily within a metropolitan area.[142] States are required to prepare plans for implementing an AFV program and various policy incentives that may be used to encourage the adoption of AFVs.[143] The mandatory acquisition schedule of AFVs for *state government* fleets is: 10 percent for model year 1997; 15 percent for model year 1998; 25 percent for model year 1999; 50 percent for model year 2000; and 75 percent for model year 2001 and thereafter.[144] (See Table A4-7.)

Table A4-7. EPAct Requirements for Light-Duty AFV Acquisition for State Fleets

Model Year Vehicle Acquired	Percentage of AFVs Required
MY1997	10 percent
MY1998	15 percent
MY1999	25 percent
MY2000	50 percent
MY2001 and thereafter	75 percent

[138] See Puget Sound Clean Cities Coalition, *Court Finds Federal Government Not Meeting Alternative Fuel Vehicle Requirements* (August 8, 2002), http://www.cityofseattle.net/cleancities/EPAct%20Ruling.htm.
[139] EPAct §501; 10 CFR 490.303.
[140] EPAct §501. See generally 10 CFR 490.
[141] 10 CFR 490.302.
[142] See *Federal Register*, Volume 61, Number 51, pages 10627-10628.
[143] EPAct §409.
[144] EPAct §507(o); 10 CFR 490.201.

Like the Federal program, alternative fuel providers and state fleets earn one credit for every light-duty AFV acquired every year above the base AFV acquisition requirements. Once they have satisfied their annual light-duty AFV acquisition requirements, covered fleets may also earn one credit for every heavy-duty AFV acquired annually. Again, these credits are freely transferable between fleets, or can be banked for future years. DOE has created a Credit Trades Bulletin Board to assist fleets in buying or selling AFV credits.[145]

Other EPAct Incentives for AFVs

The following additional provisions may encourage the use of alternative fuels:

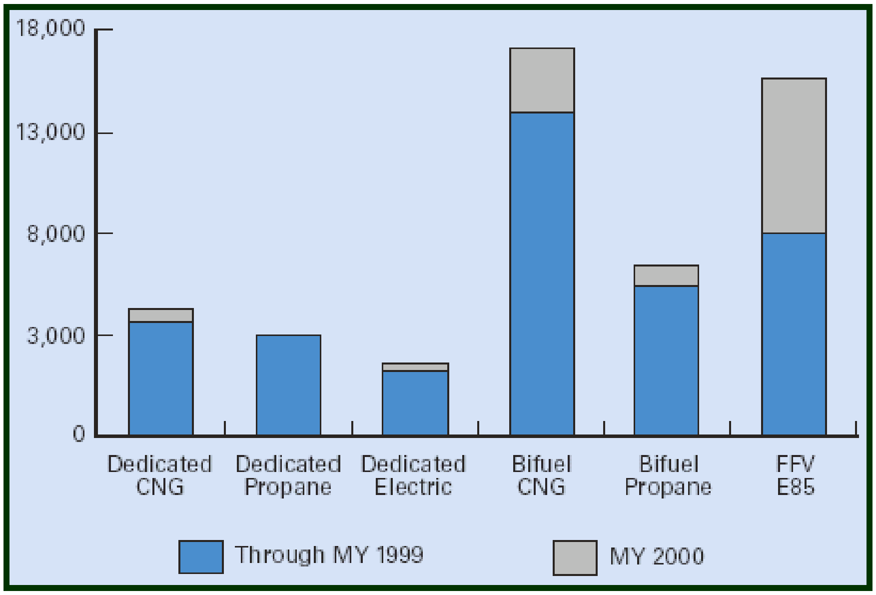
- Up to $30 million/year to assist in the purchase of alternate fuel transit buses and school buses for public and private fleets;
- $25 million/year for low-interest loans for the purchase of AFVs for public and private fleets;
- State and local incentive programs, including $10 million/year to assist states in acquiring AFVs;
- Exemption for vehicular natural gas from certain Federal and State regulations;
- Certification of training programs for alternate fuel vehicle technicians; and
- Public information programs.

Success of the EPAct AFV Program for State and Alternative Fuel Provider Fleets

According to the 2001 annual report for the State & Alternative Fuel Provider (S&FP) program, covered fleets were required to purchase a total of 13,501 light-duty AFVs in MY2000. The fleets slightly exceeded this number, purchasing a total of 13,541 light-duty AFVs. In addition, fleets banked an excess of 4,101 credits during MY2000. As shown in Figure A4-1, dedicate and bi-fuel LPG vehicles were an important part of AFV acquisitions by S&FP fleets.

[145] EPAct 508(d); 10 CFR 409. See also Alternative Fuel Transportation Program, Final Rule, 10 CFR Part 490), http://www.fleets.doe.gov/cgi-bin/fleet/main.cgi?17357,state_ins_rep,5,468050. See also http://www.ott.doe.gov/epact/state_fleets.shtml for more information.

Figure A4-1. Total AFV Acquisitions under the S&FP Program



Source: U.S. Department of Energy, *State & Alternative Fuel Provider Program Annual Report*, http://www.ott.doe.gov/epact/pdfs/fy01rpt.pdf.

For MY2000, a total of 376 credits were traded by 12 fleets, accounting for less than 2% of the total credit activity for MY 2001. In combination with the fact that the total number of credits banked by fleets remains at the high level of 46,155, this suggests most fleets are saving credits for their own use. During MY 2000, fleets used 2,759 banked credits towards meeting their compliance requirements.[146]

According to the 2001 Annual Report, only about 9% of the S&FP fleets had failed to comply with program requirements[147] Figures 2-2 and 2-3 indicate overall compliance and vehicle acquisition trends in state and alternative fuel provider fleets.

[146] U.S. Department of Energy Office of Transportation Technologies, "Program Activity and Accomplishments in FY2001," (Washington, D.C., December 2001),http://www.ott.doe.gov/epact/pdfs/fy01rpt.pdf.
[147] Ibid.

Figure A4-2. Compliance Trends in the S&FP Program

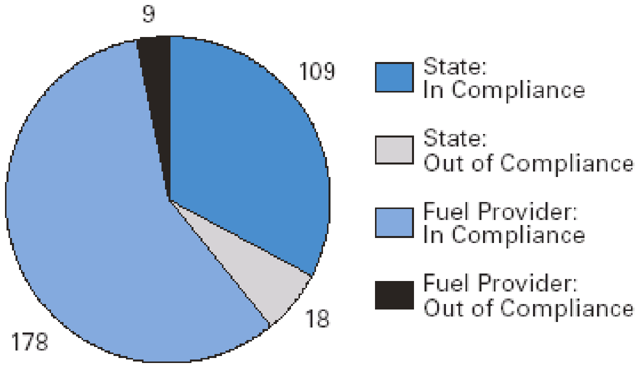
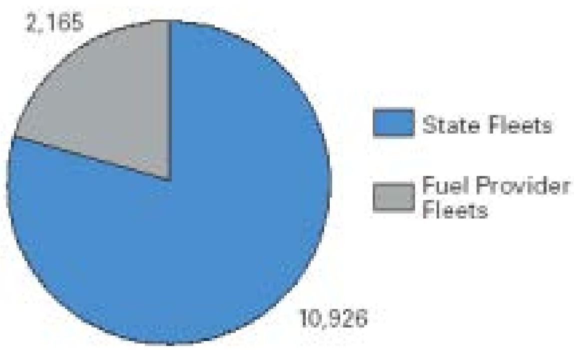


Figure A4-3. Total Vehicle Acquisitions in the S&FP Program through 2001



Source: U.S. Department of Energy, *State & Alternative Fuel Provider Program Annual Report*, http://www.ott.doe.gov/epact/pdfs/fy01rpt.pdf

Preliminary results of MY2001 acquisitions reported in Spring 2002 indicated that states and alternative fuel provider fleets collectively acquired more than 60,000 AFVs since the launch of the program, again exceeding the program quota.[148]

[148] U.S. Department of Energy Office of Transportation Technologies, "What's New: Spring 2002 Update," (Washington, D.C., May 2002), http://www.ott.doe.gov/epact/pdfs/whatsnew_spring_02.pdf.

EPAct Procurement Requirements and Incentives for AFVs in Local Government and Private Fleets

Pursuant to EPAct Section 507(g), the Department of Energy is required to consider adopting and implementing an AFV acquisition program for other fleets, i.e., local government and private fleets.[149] Before implementing a potential Private and Local Government (P&LG) fleet program, DOE must also determine whether doing so would be necessary to help meet the EPAct's U.S. petroleum replacement fuel goals, and that it is technically and economically practical.[150] The DOE may also consider whether to include law enforcement motor vehicles and new urban buses as part of the program.[151]

Under such a prospective program, local governments or private fleets would be covered if they own or operate at least 50 light-duty vehicles in the U.S., 20 of which are primarily used within a metropolitan statistical area.[152] As noted earlier, a federal court ordered DOE publish a proposed rule on private and local government fleets by the end of January 2003 and issue a final rule by the end of November 2003.[153] EPAct outlines the percentage of AFVs that would have to be acquired for each model year, should DOE adopt such a program, as shown in Table A4-8.

Table A4-8. EPAct Requirements for Light-duty AFV Acquisition for All Other Fleets

Model Year Vehicle Acquired	Percentage of AFVs Required
MY1999, 2000, 2001	20 percent
MY2002	30 percent
MY2003	40 percent
MY2004	50 percent
MY2005	60 percent
MY2006 and thereafter	70 percent

A4.1.3 Clean Air Act of 1970 and Clean Air Act Amendments of 1990

General Provisions

The Clean Air Act (CAA), first enacted in 1970 and later amended in 1990, provides the basis for the Federal government's authority to address, through the U.S. Environmental Protection Agency, air pollution throughout the United States, including the regulation of emissions from stationary and mobile sources. Starting with Chapter 202 of the 1990 Amendments, the CAA establishes emission and fuel standards for mobile sources, and provides standards for clean-fuel vehicles, including light-duty clean-fuel vehicles, light-duty trucks, and flexible and dual-fuel vehicles.[154] The CAA also allows the State of California to promulgate its own standards for clean-fuel vehicles.[155]

[149] EPAct §507(e).
[150] EPAct §507(a)(3). See DOE website at http://www.ott.doe.gov/epact/private_fleets.shtml.
[151] EPAct §507(k).
[152] EPAct §301.
[153] See http://cityofseattle.net/cleancities/EPAct%20Ruling.htm.
[154] CAA §243. Under the Act, "clean fuels" are defined as natural gas, ethanol, methanol or other alcohols; mixtures containing 85 percent or more methanol, ethanol or other alcohols; reformulated gasoline and diesel; LPG; electricity; and hydrogen. CAA §241.
[155] CAA §243.

Clean Fuel Fleet Program

The 1990 Amendments also established the Clean Fuel Fleet (CFF) Program that requires "covered fleets" with 10 or more vehicles owned by public or private entities in Consolidated Metropolitan Statistical Areas (CMSAs)[156] to acquire clean-fuel vehicles (CFVs) when replacing existing vehicles. Under the Act, states would have the option of adopting an alternative program under the state's State Implementation Plan under the CAA, so long as the state would meet the equivalent reductions in ambient emissions. To date, CMSAs that states have opted to include in the CFF Program include Atlanta, Georgia; Chicago-Gary-Lake County, Illinois/Indiana; Denver-Boulder, Colorado; and Milwaukee-Racine, Wisconsin.

As required under the CAA, starting in model year 1999, 30 percent of new light-duty vehicles and 50 percent of newly acquired medium- and heavy-duty vehicles (i.e., 8,500 - 26,000 gross vehicle weight) were required to be clean-fuel vehicles. (Fleets composed of law enforcement and emergency vehicles are exempt from the requirements.) Required procurement levels increase in following years, as detailed in Table A4-9.

Table A4-9. Purchasing Requirements under the Clean Fuel Fleet Program[157]

Vehicle Size	1999	2000	2001 and later
GVW Rated less than 8,500 lbs	30%	50%	70%
GVW Rated less than 26,500 lbs	50%	50%	50%

The CFF Program offers credits for each clean-fuel vehicle purchased under the program, based on the emission level of the vehicle. Low emission vehicles (LEVs) receive one credit, ultra-low emission vehicles (ULEVs) receive two credits, and zero emission vehicles (ZEVs) receive three credits each. Credits may be used to demonstrate compliance with the program, and may be freely traded to meet compliance requirements by participating fleets as needed.[158]

A4.1.4 Federal "Inherently Low-Emission Airport Vehicle" (ILEAV) Pilot Project

In 2000, Congress passed the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century, which included provisions to establish a $20 million program to introduce low emission vehicles at 10 airports identified by the Department of Transportation that are located in air quality non-attainment areas as defined by the Clean Air Act.[159] Under the law, the Federal government commits 50 percent of the funding for the pilot projects to introduce LPG and other clean-fuel vehicles to airport fleets, as well as to implement clean-fuel infrastructure.[160]

In May 2001, the Federal Aviation Administration (FAA) announced the 10 airports selected for the ILEAV program out of 40 that had expressed interest. The selected airports are: Baltimore-Washington International; Baton Rouge, Louisiana; Chicago O'Hare International; Dallas/Fort Worth International; Denver International; Hartsfield Atlanta International; New York's John F. Kennedy International; New York LaGuardia; Sacramento International; and San Francisco

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[156] CAA §241(5). CMSAs include cities are metropolitan areas that had a population of at least 250,000 in 1980 and have been classified as extreme, severe, or serious non-attainment areas for ozone as defined by the CAA. At the time of the passage of the CAA Amendments in 1990, 22 metropolitan areas would have qualified.
[157] CAA §246. See also National Alternative Fuels Hotline, *The Clean Fuel Fleet Program* (September 1998), http://www.afdc.doe.gov/pdfs/caaa.pdf.
[158] CAA §246.
[159] Public Law No: 106-181, Section 133.
[160] Ibid.

International. Of these airports, currently only Sacramento has plans to include LPG vehicles in its ILEAV pilot project.[161]

A4.2 State Laws and Policies

A growing number of states have adopted policy measures promoting the use of AFVs. Some of the larger programs, such as those in California and several northeastern states, are discussed below.

Section 209(a) of the Clean Air Act prohibits states from adopting or enforcing standards for new motor vehicles or new motor vehicle engines—with the exception of the State of California.[162] In response to California's severe air pollution problems, CAA Chapter 209(b) grants the state the explicit authority to set its own standards for vehicular emissions, so long as the standards are (1) equal to or more stringent than those set by the CAA and (2) are approved by EPA.[163] State studies have found that about half of smog-forming pollutants are produced by gasoline and diesel-powered vehicles, and that only alternative technologies would help California reduce the motor vehicle air pollution that will result from increasing driving rates in the State.[164]

California's response to its severe air quality problems was the adoption of a series of regulations in the 1990s to promote the adoption of new LEVs and ZEVs in the state. The Clean Air Act permits other states to follow California so long as any motor vehicle emissions regulations adopted by those states are identical to California's.[165] Since California introduced its LEV standards in 1990, four other States— Maine, Massachusetts, New York, and Vermont—have adopted the California emissions requirements for a percentage of motor vehicles sold in those states.

As of this time, only a few light-duty LPG vehicles meet several of the strict emissions standards established under the LEV and ZEV programs. A list of these vehicles is provided in Table A4-13, below.

In addition to the LEV provisions, the State of California has adopted a number of policies and undertaken a wide range of programs promoting AFVs in the state. LPG vehicles have significant potential to displace petroleum fuels and provide air quality benefits in California. However, the limited number of dedicated LPG vehicles and a lack of infrastructure development for passenger vehicles restrict this potential.[166]

A4.2.1 California Low Emission Vehicle (LEV) Regulatory Program

The flexibility provided to California under the CAA paved the way for sweeping regulation that has established extensive standards for low and zero emissions vehicles sold in the State. In 1990 the California Air Resources Board (CARB) adopted the first set of regulations to require automobile manufacturers to introduce LEVs to the California automobile market. The regulations require manufacturers to sell a certain percentage of these vehicles each year. Known as LEV I, the new standards promised to affect the entire automobile market in California by introducing various new LEVs, including LPG vehicles.

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[161] http://www2.faa.gov/arp/app600/ileav/Rpt1_3_31_02.doc.
[162] 42 U.S.C. 7609(a).
[163] 42 U.S.C. 7609(b).
[164] California Air Resources Board, California's Zero Emission Vehicle Program, "Fact Sheet," California Air Resources Board (December 26, 2001), http://www.arb.ca.gov/msprog/zevprog/factsheet/evfacts.pdf.
[165] 42 U.S.C. 7507.
[166] California Energy Commission, "California Clean Fuel Market Assessment 2001," P600-01-018 (September 2001), Section 1.2. http://www.energy.ca.gov/reports/2001-09-18_600-01-018.PDF.

LEV I standards were based on the introduction of four classes of vehicles with increasingly more stringent emissions requirements. Under the LEV I requirements, manufacturers were permitted to certify vehicles in any combination of the LEV categories from 1994 through 2003 in order to satisfy the LEV standard.[167] It should be noted that under current regulations, auto manufacturers are also required to comply with a fleet-based average Non-Methane Organic Gas standard (NMOG), which introduces more and more stringent standards with each model year.[168]

Following a hearing in November 1998, the CARB amended the LEV I regulations and adopted LEV II, the second-generation LEV program. While the first set of LEV standards covered 1994 through 2003 models years, the LEV II regulations cover 2004 through 2010 and represent continued emission reductions. The LEV II amendments were formally adopted by the CARB on August 5, 1999 and came into effect on November 27, 1999.[169]

Under LEV II, manufacturers may certify vehicles under one of five emission standards, listed in order from least to most stringent:

- transitional low emissions vehicles (TLEVs)
- low-emission vehicles (LEVs);
- ultra-low-emission vehicles (ULEVs);
- super ultra-low emissions vehicles (SULEVs); and
- zero emissions vehicles (ZEVs).

The more stringent LEV II regulations were adopted in part to keep up with changing passenger vehicle fleets in the state, where more sport utility vehicles (SUVs) and pickup trucks are used as passenger cars rather than work vehicles. The LEV II standards were a necessary step for the state to meet the Federally-mandated CAA goals that address ambient air quality standards as outlined in the 1994 State Implementation Plan (SIP).[170] LEV II increased the stringency of the emission standards for all light- and medium-duty vehicles beginning with the 2004 model year and expanded the category of light-duty trucks up to 8,500 lbs. gross vehicle weight (including almost all SUVs) to be subject to the same standards as passenger cars.[171] When LEV II is fully implemented in 2010, it is estimated that smog-forming emissions in the Los Angeles area will be reduced by 57 tons per day, while the statewide reduction is expected to be 155 tons per day.[172]

The LEV II standards go further to require that vehicles classified as LEV and ULEV meet NO_x standards which are 75 percent below LEV I requirements based on fleet averages. In addition, fleet average durability standards are extended from 100,000 to 120,000 miles. LEV II also allows manufacturers to receive credits for vehicles meeting near-zero emissions, and a new category of

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[167] See California Air Resources Board, "California Exhaust Emissions Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-duty Trucks, and Medium-Duty Vehicles," Proposed Amendments (September 28, 2001).

[168] §1960.1(g)(2). California's fleet average NMOG mechanism "requires manufacturers to introduce an incrementally cleaner mix of Tier 1, TLEV, LEV, ULEV and ZEV vehicles each year, with the fleet average NMOG value for passenger cars and lighter light-duty trucks decreasing from 0.25 gram/mile in the 1994 model year to 0.062 gram/mile in the 2003 model year." See California Air Resources Board, "The California Low-Emission Vehicle Regulations" (May 30, 2001), http://www.arb.ca.gov/msprog/levprog/cleandoc/levregs053001.pdf.

[169] California Low-Emission Vehicle Program, http://www.arb.ca.gov/msprog/levprog/levprog.htm.

[170] Ibid.

[171] California Air Resources Board: Notice Of Public Hearing To Consider The Adoption Of Amendments To The Low-Emission Vehicle Regulations, November 15, 2001, http://www.arb.ca.gov/msprog/levprog/test_proc.htm.

[172] California LEV Program, http://www.arb.ca.gov/msprog/levprog/levprog.htm. See also The California Low-Emission Vehicle Regulations, http://www.arb.ca.gov/msprog/levprog/test_proc.htm).

vehicles called super ultra-low emissions vehicles (SULEVs).[173] The LEV II standards were also designed to respond to some delays and "inertia" the LEV program had been facing, and pushed back the starting year of the program to 2003.

Some examples of LEV I and LEV II emissions standards for the different vehicles types are provided in Tables A4-10 and A4-11.

Table A4-10. LEV I Exhaust Emission Standards for New MY2001-MY2003 Passenger Cars and Light-Duty Trucks (3,750 lbs. GVW or less)

Durability of Vehicle	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	NOx (g/mi)	Formaldehyde (mg/mi)	Particulates fr. diesel vehicles (g/mi)
50,000	Tier 1	0.250	3.4	0.4	n/a	0.08
	TLEV	0.125	3.4	0.4	15	n/a
	LEV	0.075	3.4	0.2	15	n/a
	ULEV	0.040	1.7	0.2	8	n/a
100,000	Tier 1	0.310	4.2	0.6	n/a	n/a
	Tier 1 diesel option	0.310	4.2	1.0	n/a	n/a
	TLEV	0.156	4.2	0.6	18	0.08
	LEV	0.090	4.2	0.3	18	0.08
	ULEV	0.055	2.1	0.3	11	0.04

[173] See California Air Resources Board, "California Exhaust Emissions Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-duty Trucks, and Medium-Duty Vehicles," Proposed Amendments (Sept. 28, 2001).

Table A4-11.LEV II Exhaust Emission Standards for New MY2001-MY2003 Passenger Cars and Light-Duty Trucks (8,500 lbs. GVW or less)

Durability of Vehicle	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	NOx (g/mi)	Formaldehyde (mg/mi)	Particulates fr. diesel vehicles (g/mi)
50,000	LEV	0.075	3.4	0.05	15	n/a
	LEV Option 1	0.075	3.4	0.07	15	n/a
	ULEV	0.040	1.7	0.05	8	n/a
120,000	LEV	0.090	4.2	0.07	18	0.01
	LEV Option 1	0.090	4.2	0.10	18	0.01
	ULEV	0.055	2.1	0.07	11	0.01
	SULEV	0.010	1.0	0.02	4	0.01
150,000 (optional)	LEV	0.090	4.2	0.07	18	0.01
	LEV Option 1	0.090	4.2	0.10	18	0.01
	ULEV	0.055	2.1	0.07	11	0.01
	SULEV	0.010	1.0	0.02	4	0.01
	LEV	0.090	4.2	0.3	18	0.08
	ULEV	0.055	2.1	0.3	11	0.04

To date, seven LPG vehicles have been developed that meet the California LEV and ZEV standards, as shown in Table A4-13.

Table A4-13 Examples of Light-Duty LPG Vehicles Meeting California Emission Standards as of 2002[174]

Make and Model	California LEV II	Fuel Displacement
Trucks, Vans, and SUVs		
Chevrolet G2500 Express	ULEV	5.7 L
Chevrolet G3500 Express	ULEV	5.7 L
Chevrolet G3500 Van	ULEV	5.7 L
GMC G2500 Savana Passenger Van	ULEV	5.7 L
GMC G3500 Savana Passenger Van	ULEV	5.7 L
GMC G2500 Savana Cargo	ULEV	5.7 L
GMC G3500 Savana Cargo	ULEV	5.7 L

[174] California Air Resources Board, AB71 Eligible Vehicles - Single Occupant Carpool Lane Use Stickers (June 6, 2002), http://www.arb.ca.gov/msprog/ccbg/ccbg.htm.

A4.2.2 Adoption of California LEV II Standards in Northeastern States

As discussed above, California is the only State permitted to adopt motor vehicle emissions standards that exceed those of the CAA.[175] However, under Chapter 177 of the CAA, other States are permitted to adopt any regulations to address motor vehicle emissions that are enacted and adopted by California, so long as the regulations are no more stringent than California's standards and the regulations come into effect no sooner than two years after the applicable California model year.

In the early 1990s, Maine, Massachusetts, New York, and Vermont adopted the California LEV standards. With the exception of Maine, which has repealed its California-based ZEV regulations,[176] each of those states has adopted the 10 percent ZEV sales mandate commencing in model year 2005, two years after the California start year of 2003. In 2000 and 2001, respectively, New York and Massachusetts took the further steps of adopting California's LEV II regulations, as amended.[177] Vermont has yet to adopt the most recently amended LEV II regulations, but is expected to do so. Beginning in model year 2005, New York also will require the LEV II program for medium-duty vehicles, including larger pick-up trucks and SUVs weighing between 8,500 and 14,000 pounds.[178]

A4.2.3 Other State Programs

Other states have instituted a wide range of policy measures and programs designed to promote the use of LPG vehicles and other AFVs. Such programs include monetary and non-fiscal incentives. Monetary incentives include:

- Individual income tax credit or deduction (AZ, GA, KS, LA, MD, MT, NJ, NY, RI, UT, VA, WV)
- Retail sales tax reduction or exemption (AZ, CO, CT, ME)
- License or titling fee reduction (AZ, CA, FL, ME, VA)
- Corporate tax credit or deduction (CT, OR, VA)
- Grants or Rebates to individuals (AR, CA, CO, IL, IN, MD, NY, NY, OK, PA, TX)
- Grants or rebates to local governments (DE, FL, GA, NJ, NY, PA, TX, VA, WI, WV)
- Grant to small business (IN)
- Low interest loans to local governments (IA, MO, OK, UT)[179]

Non-fiscal incentives for AFVs include:

- Permission to use high occupancy vehicle (HOV) lanes with fewer than the required number of vehicle occupants. This incentive is offered in at least six states (AZ, CA, CO, GA, HI, VA)

[175] 42 U.S.C. 4709(b).
[176] See State of Maine Department of Environmental Protection, Rule Chapter 127, *New Motor Vehicle Emission Standard,* Basis Statement for Amendments of December 21, 2000.
[177] In 1993, Maryland and New Jersey also adopted the California LEV program, provided that surrounding States also adopt the California standards. EVAA, State Laws and Regulations Impacting Electric Vehicles (January 2002), http://www.evaa.org.
[178] Office of the Governor of New York, *Regulation to Reduce Harmful Vehicle Emissions, Alternative to Promote Clean Vehicle Technology, Improve Air Quality*. (January 4, 2002), http://www.state.ny.us/governor/press/year02/jan4_02.htm; See also "New York Adopts New California Emission Standards," *EarthVision Environmental News*, November 29, 2000, http://www.climateark.org/articles/2000/4th/nyadnewc.htm.
[179] "State Incentives for Cleaner Transportation Technologies," Prepared for U.S. Environmental Protection Agency, Office of Policy Analysis and Review, Washington, DC, September 2001. See http://www.epa.gov/otaq/market/rpt914.htm#_Toc5.

- Preferential parking spaces provided at employment locations. This incentive is often promoted by local Clean Cities coalitions.
- Preferential curbside parking for alternative fueled delivery truck in urban areas. New York City has proposed a program called "Green Stripe Parking" that allows short-term curbside parking for alternative-fueled delivery trucks.
- In-kind resources to encourage local governments (and possibly the private sector) to establish an alternative fuels program, e.g., free training on AFV maintenance for municipal fleet managers (various states).[180]

A4.2.4 California Regulation of GHG Emissions from Motor Vehicles

On July 11, 2002, the California Legislature passed landmark legislation to propose adopting the first GHG emission regulations on motor vehicles in the United States. Signed into law on July 22, 2002 by the Governor of California, AB 1493 could significantly build on the objectives of the State's LEV and ZEV program. The law requires the CARB to adopt regulations for carbon dioxide emissions from passenger cars, light trucks, and SUVs by January 1, 2005. The bill directs the CARB to adopt regulations "that achieve the maximum feasible reduction of GHGs emitted by passenger vehicles and light-duty trucks and any other vehicles" in the state.[181] The law would take effect January 1, 2006 and would apply to vehicles manufactured in the 2009 model year and after. One interesting provision in the final legislation requires CARB to develop regulations that specifically do not: (1) impose additional fees or taxes on motor vehicles, fuel, or miles traveled; (2) ban the sale of any vehicle category in the state; (3) require reductions in vehicle weight; (4) limit speed limits; or (5) limit vehicle miles traveled. AB 1493 would also require the California Climate Action Registry to develop procedures by July 1, 2003, in consultation with CARB, for the reporting and registering of vehicular GHG reductions to the Registry. (The California Registry is described in greater detail in Chapter 4. As stipulated in the Clean Air Act, two years after AB 1493 is signed into law, other states would be able to follow California in adopting equally stringent regulation of carbon dioxide emissions from automobiles.

A4.2.5 California Clean Fuel Availability Requirements

To help promote the use of LPG and other alternative fuels (including natural gas, methanol, and ethanol) in California, the CARB adopted additional rules requiring owners or operators of fuel stations to install fueling facilities at their stations. Under the regulations, for example, once vehicle manufacturers produce 20,000 AFVs for a particular alternative fuel, this would "trigger" the requirement for installation of fueling facilities.[182] The provisions cease to apply to each designated clean fuel once the number of retail clean fuel outlets offering the designated clean fuel represent at least 10 percent of all retail gasoline outlets in the state. [183]

A4.2.6 New York AFV Purchasing Requirements

The State of New York has taken several aggressive steps to promote the use of AFVs. On June 10, 2001, New York's Governor Pataki signed Executive Order No. 111 in an effort to exceed Federal AFV acquisition requirements under EPAct. Executive Order No. 111 requires all state government entities to met new acquisition requirements, regardless of the size of the fleets or where they are located. (Specialty, police, and emergency vehicles are exempted.) By 2005, at least 50 percent of all new light-duty vehicles acquired by each fleet must be AFVs. After 2005,

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[180] See http://www.LPGvehicle.org/mainpages/vehicles/policy.php.
[181] California, AB 1493 (as amended, May 31, 2001).
[182] Final Regulation Order, Amendments to the Regulations for the California Clean Fuels Program, see 13 CCR §§2300-2317.
[183] 13 CCR §2318.

annual acquisition requirements must increase by 10 percent each year until 2010, when 100 percent of all new acquisitions will be AFVs.[184]

A4.3 Other Activities Promoting LPG Vehicles

DOE Clean Cities Program

Sponsored by DOE, the Clean Cities Program is designed to promote public-private partnerships to deploy AFVs and their supporting infrastructure. By encouraging AFV use, the Clean Cities program helps to achieve energy security and environmental quality goals on local, national, and international levels. Two principal goals of the program are to deploy one million AFVs operating exclusively on alternative fuels by 2010, and to promote one billion gasoline gallon equivalents of clean fuels used in AFVs by 2010.[185]

The Clean Cities program takes a voluntary approach to AFV development, working with coalitions of local stakeholders to help develop local strategies and initiatives to integrate AFVs into the local transportation sector. Participating cities in the program include:

- 77 Clean Cities coalitions in 41 states;
- 3 border programs with the cities of El Paso, Texas and Juarez, Mexico; Detroit, Michigan and Toronto, Canada; and Grand Forks, North Dakota and Winnipeg, Canada; and
- International programs in Chile, Brazil, Central America and the Caribbean, India, Mexico, Peru, and the Philippines.

The DOE Clean Cities International Program began as a result of the Hemispheric Energy Symposium held in October 1995 in follow-up to the December 1994 Summit of the Americas to promote energy cooperation and sustainable development.[186]

U.S. Department of Transportation Programs

In May 1999, the U.S. DOT announced that it was forming the Center for Global Climate Change and Environment to conduct scientific research on emerging technologies and alternative fuels to deal with carbon dioxide emissions from transportation sources. To address transportation issues related to climate change and global warming, officials from DOT said that the research center would focus on new technologies to achieve higher fuel efficiency, tax credits for fuel-efficient cars, changes in travel behavior, and transportation planning as part of community development. During the opening session, former Transportation Secretary Rodney Slater noted that transportation accounts for 26 percent of U.S. GHG emissions and that the new center would work closely with the Environmental Protection Agency and the Department of Energy to promote the development of low-emitting transportation technologies.

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[184] New York State Energy Research and Development Authority, *Executive Order No. 111 "Green and Clean" State Buildings and Vehicles Guidelines* (December 2001), p.21. See http://www.nyserda.org/exorder111guidelines.pdf.

[185] See Clean Cities website, at http://www.ccities.doe.gov.

[186] For more information, see http://www.ccities.doe.gov. Project developers may also contact the Clean Cities Hotline at 1-800-CCITIES for additional information.

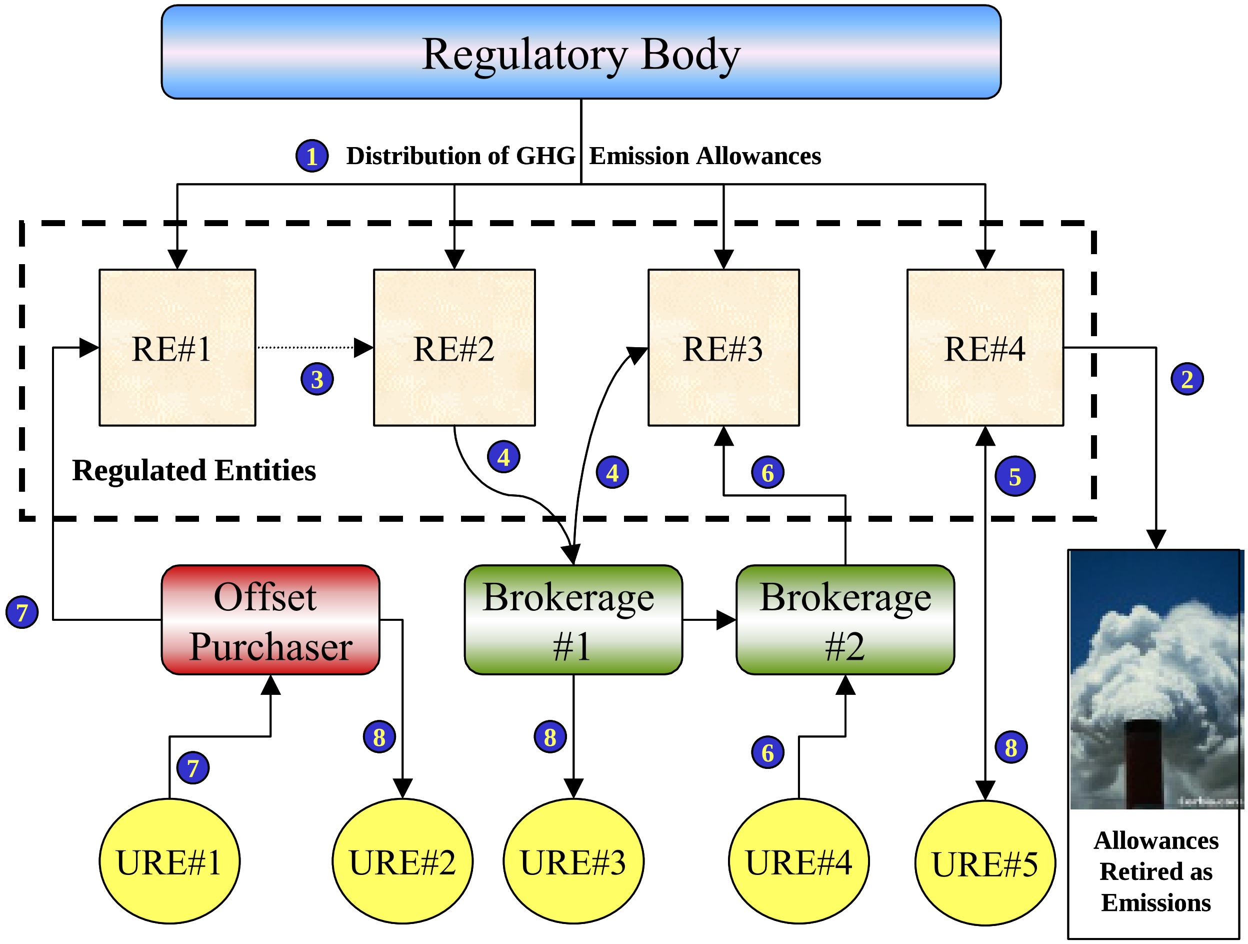
A5. Emissions Trading Market Summary

The various programs, funds, and regulations described in Chapter 3 all serve to make up the framework of the GHG emission trading market. Brokerage firms play the usual role of bringing buyers and sellers together, and in some cases, may also work to facilitate project development.

Figure A5-1 illustrates the various trading pathways that can take place in a GHG trading system and provides a list of common transactions. The bullet numbers correspond to the transaction label numbers illustrated in Figure A5-1. Arrows indicate the direction of the transaction.

1. The regulatory body distributes or auctions GHG emission allowances to the regulated entities.
2. These emission allowances can be used to emit GHGs.
3. If one entity takes action to reduce emissions on site and has allowances to spare, the entity may sell these allowances directly to other entities that may have exceeded their allotted share of emissions.
4. Alternatively, the entity may sell the allowance through an independent commercial brokerage.
5. A regulated entity in need of allowances may purchase offsets directly from an unregulated entity that has undertaken GHG emission reductions according to the specific requirements of the trading/offsets program.
6. Alternatively, the unregulated entity may sell those offsets through a brokerage.
7. If an aggregate offset purchaser is involved, it may purchase qualifying offsets from unregulated entities and use these offsets to meet the emission reduction goals of the offset purchaser's investors, some of which may include one or more regulated entities.
8. Unregulated entities may purchase offsets to meet their own voluntary goals from brokerage houses, regulated entities or aggregate offset purchasers.

Figure A5-1. Emissions Trading System with a Project-Based Offset Program



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U.S. Department of Energy
National Energy Technology Laboratory (NETL)
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
http://www.netl.doe.gov

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