Asia-Pacific Economic Cooperation

Alternative Transport Fuels: Implementation Guidelines

APEC Energy Working Group

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SUMMARY

There are at least 35 million vehicles worldwide already operating on some form of alternative transport fuel and many millions more that are fuelled by blends with conventional gasoline and diesel or powered by electricity. Many alternative fuel programs are being, or have been, implemented mostly in response to the oil price increases that have occurred over the last decade, the desire to increase energy security and concerns about urban air pollution. Despite the current economic downturn, it is expected that the uptake of alternative transport fuels will continue to increase.

The alternative transport fuels that have been, or are likely to be, produced in one or more APEC economies include:

- Natural gas, including compressed and liquefied natural gas (CNG and LNG) and biomethane,
- Autogas (LPG used as an automotive fuel),
- Alcohols (ethanol and methanol),
- Biodiesel,
- Hydrogen,
- Electricity.

Petroleum fuels produced from natural gas and coal via Fischer-Tropsch synthesis, or other chemical processes, are also included.

For the purposes of this report, which is intended to develop guidelines for the implementation of alternative transport fuels, only those fuels that have been introduced on a commercial scale have been studied in depth. Thus, while recognising that hydrogen and fuel cells, for example, may well be the fuel and fuel system of the future they have not yet been introduced into the market so few lessons can be learned from their commercialization.

There are several key issues that are integral to the successful introduction of alternative transport fuels. These include:

- Establishment of an alternative fuel distribution system,
- Conversion of vehicles, or development of OEM vehicles, to use an alternative fuel,
- Establishment of standards, industry codes of practice and regulations to ensure the safe operation of all aspects of fuel distribution and use,

- Achievement of consumer acceptance and market penetration,
- Ensuring that the alternative transport fuel is sustainable.

Those alternative transport fuels that have achieved significant market penetration and are now in everyday commercial use are listed in Table 1, which shows that natural gas has the highest level of consumption as an automotive fuel worldwide, followed quite closely by autogas and ethanol. Uptake of NGVs in APEC economies is only about half that of autogas and ethanol. Otherwise, the great majority of battery electric vehicles (EV) (mainly scooters and bikes in China) and hybrid electric vehicles (HEVs) are to be found in APEC economies.

Table 1: Alternative Transport Fuels in Widespread Commercial Use

	Vehicle Numbers			Fuel Consumption (PJ/year)			Year
Alternative Fuel	Worldwide (000)	APEC (000)	APEC %	Worldwide	APEC	APEC %	
Gaseous Fuels							
CNG/LNG/Biomethane	9,076	790	8.7	1,119	280	25.0	2,008
Autogas (LPG)	9,531	3,829	40.2	871	474	54.5	2,006
Alcohols							
Ethanol	14,706	7,576	51.5	828	459	55.4	2,007
System Compatable Fuels							
Biodiesel				361	135	37.4	2,008
Synthetic hydrocarbons				355	0	0.0	2,007
Electricity							
Battery Electric Vehicles	45,261	45,226	99.9	109	109	99.9	2,007
Hybrid Electric Vehicles	1,078	1,032	95.7	8	7	95.7	2,007
Totals	**79,652**	**58,453**	**59.2%**	**3,650**	**1,464**	**52.6%**	

Several impediments to the introduction of alternative transport fuels have been identified. The most common are:

- Inadequate fuel supply and refuelling infrastructure,
- Ease of access to refuelling outlets,
- Slow development of standards, codes and regulations and the institutional framework for their administration,

- The additional costs associated with the purchase or conversion of an alternative fuel vehicle (AFV),
- Lack of public confidence.

Introduction of an alternative transport fuel requires the provision of incentives. These are most commonly provided by government but can also be offered by industry participants (usually the fuel supplier) and are occasionally provided by the market itself. Incentives that have been used to encourage the introduction of alternative transport fuels include:

- Fiscal and financial incentives that relate primarily to fuel and vehicle taxes and profit-tax credits and deductions,
- Regulatory actions that involve the development of regulations for the safe use of an alternative transport fuel and mandates that require its uptake,
- Other incentives include funding for research, development and demonstration (RD&D), public education, the application of transport control measures (e.g. preferential access to high speed traffic lanes), and leadership by example through conversion of government or corporate vehicle fleets.

Incentives are effectively the control mechanism for governments to manage the rate and extent of alternative transport fuel implementation. Their appropriate application is quite a delicate balancing act as the incentives should be sufficient to ensure orderly market growth but should not be set so high that they result in boom-growth, which may impact adversely on other parts of the economy and can result in the conversion of vehicles that are no longer economical to operate when the incentives are removed.

Financial incentives are most widely used and have proved most effective in introducing alternative transport fuels. Mandates have also been used in a number of economies and are most effective when accompanied by financial incentives.

The report presents a number of case studies for the introduction of alternative transport fuels both in APEC economies and in non-APEC economies whose experience is considered particularly relevant. These case studies show that there is no universal model for the introduction of alternative transport fuels. Different models have been applied in different economies and most have been successful. Developing economies have, on balance, done a better job of introducing alternative transport fuels and creating viable and potentially sustainable industries and markets than their more developed counterparts. This is probably due to the fact that greater financial incentives are available to vehicle owners due to their lower incomes.

The case studies also show that the involvement of the government is essential for effectively progressing the aims and objectives of an alternative transport fuels program. Overall coordination of activities carried out by several different government agencies is clearly beneficial and the appointment of a coordinating or steering committee is highly desirable.

Once market forces come fully into play, an alternative transport fuel industry should become increasingly self-sustaining and the role of government should be reduced to regulating and administering the market and the industry.

It is apparent that the loss of public confidence in an alternative transport fuel, for whatever reason, can greatly inhibit industry development and the sudden removal of government support can kill an industry that is otherwise developing well. Any reduction in incentive level by government is seen as withdrawal of support by consumers and careful planning is required for decoupling government involvement as the market reaches maturity.

A number of requirements have been identified for the successful implementation of an alternative transport fuel. These include:

- Development of standards, codes and regulations,

- Establishment of economic and financial conditions so that consumers and industry participants are motivated,

- Provision of education and training for mechanics, technicians and inspectors throughout the emerging alternative transport fuel industry,

- Market creation through the introduction of incentives to motivate alternative transport fuel consumers and industry participates,

- Information dissemination and public relations activities to keep the public informed and to counteract the impact upon individuals of adverse publicity, which normally accompanies the introduction of an alternative transport fuel.

Based on the information that has been assembled, a set of guidelines for implementation of alternative transport fuels has been developed. This is intended as a tool kit or roadmap that can be used by proponents of an alternative transport fuels program. Coverage includes:

- Description of the conditions required for fuel switching,

- Identification of the drivers that operate to encourage the introduction of an alternative transport fuel,

- Program management requirements for alternative transport fuels introduction and the need for a coordinating committee with representation from both government and industry stakeholders,

- Requirements for the performance of feasibility studies that form the basis for developing an alternative transport fuels program,

- Development of an implementation plan that will serve as a roadmap for industry development,

- The way in which an alternative transport fuels program should be initiated with emphasis on the early conduct of vehicle and fuel distribution demonstration trials, the establishment of the institutional framework necessary and the development of market promotion policies and instruments.

Once these are in place, market forces must be allowed to operate with guidance and occasional assistance from government through a project coordinating committee that should function increasingly like a board of directors as the market develops.

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DATABASE

1. Introduction

For over a century, gasoline, diesel, avtur and fuel oil derived from crude oil have fuelled almost all transportation systems worldwide. Transportation currently consumes approximately 70% of all petroleum fuels.

The world has recently faced high demand side constraints on the availability of crude oil and the resulting high oil prices have greatly increased interest in alternative, lower priced, transport fuels. While there is currently a worldwide economic recession, it is highly likely that high oil prices will return as economic conditions improve.

It is, therefore, timely for APEC economies to establish which alternative transport fuels are available and suitable to them and to develop optimized strategies for their introduction to provide economic, environmental and energy security advantages.

1.1 Study Overview

Worldwide, there are at least 35 million vehicles already operating on some form of alternative transport fuel and many millions more that are fuelled by blends with conventional gasoline and diesel or powered by electricity. Many alternative fuel programs are being, or have been, implemented. Some of these have been successful and some have not. The aim of this study is to identify, analyse, and draw on these experiences to formulate a set of guidelines that APEC economies can follow to implement their own alternative transport fuel programs successfully.

In pursuing this aim, it is noted that the most of the existing alternative transport fuel programs, both within APEC and worldwide, are at various stages of the research, demonstration and development (RD&D) process and have not yet achieved full scale commercial operation. While noting many of these are RD&D activities, this study is concerned primarily with the commercial introduction of alternative transport fuels and the lessons that can be learned from these commercial experiences.

1.1.1 Objectives

The overall objectives of the study are to:

- Identify the key elements necessary for the successful introduction of alternative transport fuels that will be applicable both to individual economies and throughout APEC economies,

- Develop guidelines for the implementation of successful programs for the introduction of alternative transport fuels that will be both coherent throughout APEC economies and applicable to individual economies, Specific objectives include:

- Identify the alternative transport fuel types likely to be introduced in each APEC economy,
- Establish a database on alternative transport fuels programs throughout the APEC economies and selected programs worldwide,
- Disseminate this information throughout the APEC energy sector.

1.1.2 Coverage

The following topical areas are covered:

- All elements of the alternative transport fuel cycle, including fuel production, distribution, storage, refuelling operations and vehicle end use,
- Institutional, commercial and market factors involved in the introduction and operation of alternative transport fuels programs,
- All traditional project evaluation elements, to include environmental, social, political, economic and technical factors that relate to the use of alternative transport fuels.

1.1.3 Emphases

Emphasis is placed on identifying and evaluating:

- Drivers for each alternative transport fuels program throughout the APEC economies,
- Impediments to the introduction of alternative transport fuels and how they have been successfully overcome,
- Institutional structures and regulatory regimes required for successful introduction of alternative transport fuels,
- Commercial models that have been successful.

2. Fuel Characteristics

For the purposes of this project, an alternative transport fuel is considered to be any substance or material, not derived from petroleum that can be used to fuel a transportation system on land, sea or in the air. Those alternative transport fuels that have been, or are likely to be, introduced in one or more APEC economies include:

- Natural gas, including compressed natural gas (CNG) and LNG and biomethane,
- Liquefied petroleum gas (LPG),
- Alcohols (ethanol and methanol),
- Biodiesel,
- Hydrogen,
- Electricity.

Petroleum fuels produced from natural gas and coal via Fischer-Tropsch synthesis, or other chemical processes, are also included because they are derived from primary energy sources other than conventional crude oil. These fuels are often referred to as unconventional hydrocarbon (UHC) fuels.

With the exception of electricity, which can be used to power electric motors, all of these alternatives can be used to fuel conventional internal combustion engines, althoughdifferent degrees of engine modification and separate fuel distribution systems may be required.

UHC gasoline, avtur and diesel can, of course, be used without engine modification and distributed through the same fuel systems as their conventional equivalents.

2.1 Advantages of Alternative Transport Fuels

Alternative transport fuels offer several advantages over their conventional counterparts. Those that are the key drivers in promoting the use of alternative transport fuels are discussed in the following sections.

2.1.1 Economics

Present high demand for crude oil and petroleum products is led by China's strong economic growth and by continuing high demand in the United States. While the current economic downturn is reducing these demands in the short term, neither is likely to diminish in the foreseeable future and it is reasonable to expect that high crude oil, and thus high conventional transport fuel prices, will remain for a long time.

Over 50% of petroleum consumed in developing countries is used for transport. There must, therefore, be a continuing and increasing interest in the use of alternative transport fuels worldwide for purely economic reasons.

2.1.2 Energy Security

All APEC economies can increase their energy security by using indigenous resources, some of which can best be used as alternative transport fuels. For instance, many developing countries have natural gas resources that exceed any foreseeable use in conventional application sectors. In addition to indigenous resources like natural gas and coal, renewable energy resources such as crops and trees can be used to make renewable transport fuels.

The production of alternative transport fuels from indigenous resources will help insulate oil importing APEC economies from future high oil prices and supply shortages and enable oil exporting APEC economies to conserve or increase their oil exports.

2.1.3 Renewable Energy

Currently, there is strong interest, both throughout APEC and worldwide to increase the utilisation of renewable energy in order to achieve long term sustainability of energy supplies and decrease dependence on finite fossil energy resources.

Several alternative transport fuels (notably electricity, ethanol and biodiesel) can be derived from renewable sources of primary energy, thereby offsetting the consumption of fossil fuels.

2.1.4 Greenhouse Gas Emissions

Climate change is currently a key concern worldwide and APEC leaders have declared that every effort should be made to minimise anthropogenic emissions that may be influencing such change. The transport sector is responsible for the emission of an estimated 50% of greenhouse gases (GHGs), but the use of alternative transport fuels, particularly biofuels and electricity, can reduce these emissions.

The introduction of alternative transport fuels will, therefore, reduce GHG emissions and their contribution to climate change in line with APEC imperatives.

2.1.5 Ambient Air Quality

In recent years, local air quality in many APEC cities has deteriorated significantly due to increasing vehicle exhaust emissions. This is a particularly important issue for many Asian and Latin American cities.

Where alternative transport fuel programs have been implemented, however, cleaner air has resulted - particularly when natural gas has been used. New Delhi is an excellent example of air quality improvement brought about by the conversion of city buses and 2 and 3–wheeled, two-stroke engine vehicles to natural gas fuelling.

Alternative transport fuels coupled with newly developing vehicle technology together have the potential to reduce harmful exhaust emissions.

2.1.6 Public Health

The costs of health care, particularly in Asian cities, will continue to rise as the detrimental effects of air pollution increase. Many of these effects can be traced to vehicle exhaust emissions. Investments in vehicle exhaust emission reduction strategies, such as the introduction of alternative transport fuels, will reduce those health issues that are caused by photochemical smog, ozone, and particulate exhaust emissions.

The increased use of alternative transport fuels will, therefore, contribute to improved environmental health and a reduction of associated health costs.

2.1.7 Fuel Safety

Many alternative fuels have safety and environmental advantages over conventional petroleum fuels. Natural gas, for example, is lighter than air so it dissipates quickly in the event of a leak and has a higher ignition point and narrower flammability range than gasoline. Biodiesel (B100) is biodegradable and nontoxic so does not pose the same soil and water contamination risks as petroleum fuels.

2.2 Key Issues

There are several key issues that are integral to the successful introduction of alternative transport fuels. These include:

- Establishment of an alternative fuel distribution system,
- Effective and affordable conversion of vehicles to use alternative fuels,
- Establishment of safety regulations for all aspects of fuel distribution and use,
- Achievement of consumer acceptance and market penetration,
- Ensuring that the alternative fuel program is sustainable.

These issues are explained in the following sections.

2.2.1 Fuel Distribution

The establishment of an effective distribution system is integral to the introduction of all alternative fuels and can represent a major part of the cost of implementation.

Alternative transport fuels such as UHC fuels, biodiesel and low alcohol blends with gasoline, have the advantage that they can utilise, with minor or no modification, the extensive systems that already exist in most countries for distribution of conventional petroleum fuels.

Natural gas can be distributed using the existing gas pipeline distribution system but requires new equipment for compression to CNG and dispensing. Other gaseous fuels, such as LNG, LPG and hydrogen, require completely new equipment for their transportation, distribution and dispensing and the associated costs can make up 60-70% of the cost of implementing such fuels.

For electric vehicle the existing electricity distribution system provides the basis for the distribution infrastructure but electric (EV), hybrid (HEV) and fuel cell (FCV) vehicles require considerable investment in refuelling infrastructure and vehicle engine configuration in order to achieve general market introduction.

Probably one of the greatest problems involved in the introduction of alternative transport fuels into the market is the so-called “chicken and egg” dilemma. Fuel suppliers are reluctant to invest in extensive fuel distribution and dispensing systems until such time as there are a considerable number of alternative fuelled vehiclevehicles in operation; vehicle owners, on the other hand, are reluctant to convert to alternative fuel use until there are sufficient fuel outlets to provide a continuous supply of the new fuel.

2.2.2 Vehicle Conversion

Most alternative transport fuels require some degree of engine and vehicle modification to enable or optimize their use. For UHC fuels, biodiesel and low alcohol blends, the extent of engine modification is either negligible or small. For high alcohol or gaseous fuels, engine and vehicle modifications are quite extensive.

Historically the practice has been to modify engines that have been manufactured to use conventional gasoline or diesel to operate on the alternative fuel. This often results in sub-optimum performance (e.g. advantage cannot be taken of the high octane number of gaseous and alcohol fuels) but it does offer the advantage of allowing the engine to operate using either the alternative transport fuel or the conventional gasoline or diesel for which it was originally designed. These vehicles are said to be “Bi-fuelled”. This capability has proven to be an essential transition measure during the period required to establish an alternative transport fuels market that is supplied by purpose built engines and vehicles provided by the Original Equipment Manufacturers (OEMs).

Involvement of the OEMs is the key to the successful establishment of alternative transport fuels as each fledgling market develops. Most, if not all of the OEMs, have already done sufficient research to enable production of market-ready alternative fuelled vehicles (AFV) within as little as 18 months, but they will not commence large scale production until there is a market. Again, we have a “chicken and egg” dilemma that must be addressed.

2.2.3 Fuel Use and Safety Regulations

Gasoline and diesel have been used as transport fuels for roughly 100 years and a great deal is known about their properties and the safety precautions required for their handling and use.

While many alternative fuels have properties that make them safer than conventional gasoline and diesel, these properties are less well understood and appropriate regulations for safe handling and use need to be established. Similarly, the supporting standards and codes of practice must be adopted and industry service personnel trained and certified in their application.

There are many examples where an alternative transport fuel has been prematurely introduced into the market before the necessary standards, codes of practice and regulations have been established. The results are usually negative and market acceptance suffers. Both governments and private sector developers must ensure that the appropriate institutional infrastructure is in place at all times during the implementation of the alternative transport fuel program.

2.2.4 Consumer Acceptance

No alternative fuel can be introduced into the market unless it is accepted by consumers – otherwise there is no market.

There have been many situations where an alternative transport fuel has not been accepted by consumers – usually because they believe that the fuel is hazardous or that it is being promoted under false pretenses. Gaseous fuels are a case in point where the general public equates *"gas at high pressure"* with *"bomb."* In many cases such misconceptions are fostered mischievously by commercial competitors, environmental groups or other stakeholders who do not support the introduction of a particular alternative transport fuel.

Consumer acceptance cannot be assumed; it has to be won on the merits of the product that is being introduced to the market. One of the key issues involved in introducing an alternative transport fuel is to ensure that its performance is faultless and that the consumer perceives greater benefits, than disadvantages, from its use.

For these reasons, it is essential that an appropriate institutional and regulatory structure be in place (see Section 2.2.4), and that a professional public education campaign be mounted to ensure that consumers are fully and truthfully informed. In this regard proponents of alternative transport fuels need to concentrate in the initial stages on engaging the "early adopters" who in time will influence the larger market.

The various ways in which consumer acceptance of alternative transport fuels has been achieved are identified and reviewed in the following sections.

2.2.5 Alternative Transport Fuel Sustainability

Sustainability is a currently fashionable term used to describe satisfaction of the PESTE criteria that have long been used in feasibility studies to determine whether or not a particular project is commercially viable. The PESTE acronym refers to:

- **P**olitical acceptability,

- **E**nvironmental acceptability,
- **S**ocial acceptability,
- **T**echnical acceptability,
- **E**conomic viability.

Modern practice also undertakes to examine a project for its **C**ultural compatibility.

To be sustainable an alternative transport fuel must meet contemporary standards for each of the PESTE(C) as the key to its successful introduction into the marketplace,

There is a commonly held misconception that sustainability, once satisfied, lasts forever. This is not so. Thus, an alternative transport fuel, such as biodiesel, may be sustainable so long as the parity price of crude oil is above, say US$ 80/bbl. However, below the relevant parity price biodiesel will no longer be sustainable. Similarly, the imposition of a value on the price of carbon emissions may well move an alternative transport fuel in or out of the sustainability range.

Sustainability, therefore, depends upon the weightings and values placed upon the PESTE(C) criteria. This is why there are so many historical examples of alternative transport fuels that were sustainable over a particular period of time in a particular economy but were discontinued when conditions (usually the parity price of crude oil) changed.

Identification of the PESTE(C) sustainability criteria for each of the alternative transport fuels that have been introduced into the market is a key element of this study.

3. Implementation Experience

The Australian Institute of Petroleum (AIP) has published the current levels of alternative transport fuel use by fuel type, as illustrated in Figure 3.1. These figures provide an initial overview of the main fuels that are currently in service, the economies involved and the extent that each alternative fuel contributes to overall transport fuel use in those economies.

It should be noted, however, that there are some important lessons to be learned from the experience of several economies not illustrated in Figure 3.1. These include India, Pakistan and Korea and are discussed in the following sections.

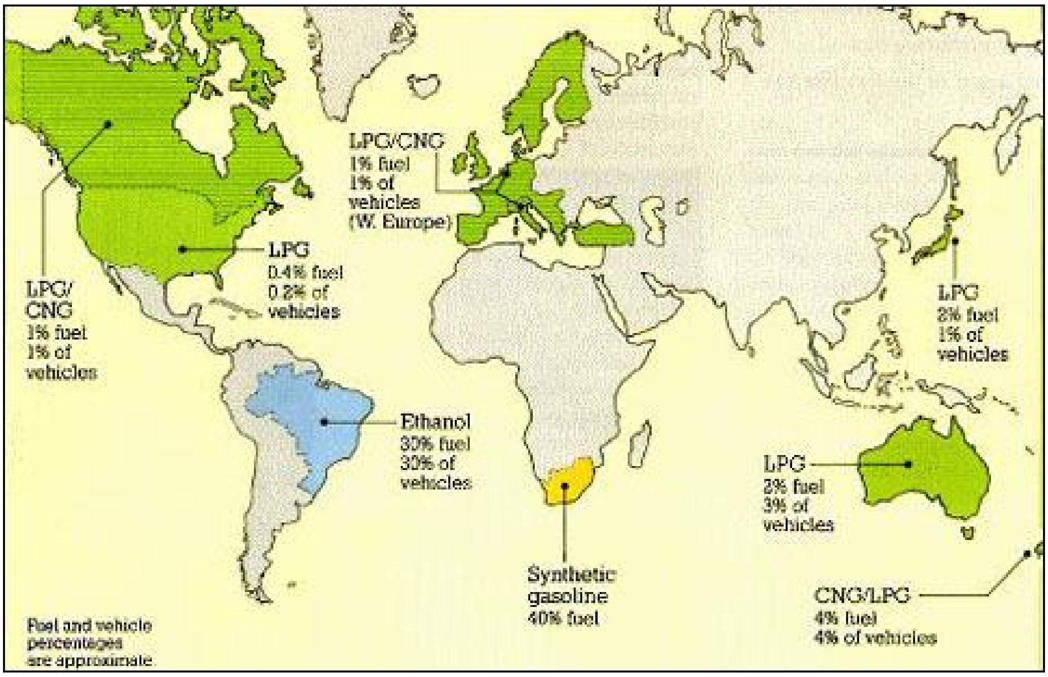

Figure 3.1: Main Alternative Transport Fuels Currently in Use (2008).

3.1 Fuel Types

The characteristics of the different alternative transport fuels considered in this study, as listed in Chapter 2, are summarized in Table 3.1.

These fuels can be grouped into similar types according to their properties, how they are formulated and the nature and extent of the modifications that need to be made to existing vehicles and fuel distribution systems.

Table 3.1: Alternative Transport Fuel Characteristics

Fuels	CNG	LNG	LPG	EtOH	MeOH	Biomethane	Biodiesel	Electricity
Energy resource	Natural gas	Natural gas	Assoc. & refinery gas	Starchy biomass	Natural gas, Coal	Biological wastes	Fats & Oils	Various
Process technology	Quality upgrade	Liquefy gas	LPG separation	Ferment & distill	Chemical processing	Digestion or Landfill	Extraction trans-ester	Power turbine
Fuel distribution	Pipeline	Insulated tanker	Presurised tanker	Liquids tanker	Liquids tanker	Compresed Pipeline	Fuel tanker	Power lines
Fuel dispensing	Gas (CNG) dispenser	LNG dispenser	LPG dispenser	Volumetric dispenser	Volumetric dispenser	Gas (CNG) dispenser	Volumetric dispenser	Electricity meter
On-vehicle storage	200 bar cylinder	Cryogenic cylinder	Low press. cylinder	Modified tank	Modified tank	200 bar cylinder	Normal tank	Batteries Fuel cell
Engine modification	Conversion OEM	Conversion OEM	Conversion OEM	Modified OEM	Modified OEM	Conversion OEM	Conversion OEM	Purpose built
Emissons	Cleanest Lower GHG	Cleanest Lower GHG	Very clean Lower GHG	Cleaner Lower GHG	Cleaner Lower GHG	Cleanest Lowest GHG	Cleaner Lowest GHG	Electricity generation
Other factors	Fossil fuel	Fossil fuel	Fossil fuel	Land use Sustainability	Fossil fuel base	Limited scale	Land use Sustainability	Source of electricity

The resulting alternative fuel types are:

- **Gaseous Fuels** (CNG, biogas, LNG, LPG, hydrogen), which require a dedicated fuel distribution system, special on-board fuel storage and moderate engine modification,
- **Alcohols** (ethanol, methanol), which require extensive modification of fuel distribution systems due to the fact that alcohols are hydrophilic (mix with water). Moderate engine modification is also required for high alcohol fuel blends,
- **System Compatible Fuels** (synthetic gasoline and diesel, biodiesel), which can be accommodated by existing fuel distribution systems and engines with very little or no modifications,
- **Electricity** (electric and hybrid vehicles, fuel cells), which involves the development of conceptually different fuel supply and vehicle engine technology.

International experience in the implementation and use of these alternative transport fuel types is presented and discussed in the following sections.

3.2 Gaseous Fuels (CNG, Biogas, LNG, LPG, Hydrogen)

Gaseous fuels require a separate fuel distribution system, separate on-board fuel storage and moderate engine modification, making them comparatively expensive to introduce as alternative transport fuels. They do, however, have the advantages of low fuel price and greatly reduced exhaust emissions compared with conventional gasoline and diesel.

3.2.1 Compressed Natural Gas (CNG) and Biomethane

Both natural gas and biomethane consist primarily of methane. Natural gas normally has methane concentrations in the range 87-96%, with the remaining components being ethane, propane, butane, higher hydrocarbons, carbon dioxide and nitrogen, as illustrated in Table 3.2.

Table 3.2: Typical Natural Gas Composition

Component	Formula	Range (Mole %)
Methane	CH_4	87.0 - 96.0
Ethane	C_2H_6	1.8 - 5.1
Propane	C_3H_8	0.1 - 1.5
Iso-Butane	C_4H_{10}	0.01 - 0.3
N-Butane	C_4H_{10}	0.01 - 0.3
Iso Pentane	C_5H_{12}	trace - 0.14
N-Pentane	C_5H_{12}	trace - 0.04
Hexanes plus	C6+	trace - 0.06
Nitrogen	N_2	1.3 - 5.6
Carbon Dioxide	CO_2	0.1 - 1.0
Oxygen	O_2	0.01 - 0.1
Hydrogen	H_2	trace - 0.02

Table 3.3: Typical Biogas Composition

Component	Formula	Range (Mole %)
Methane	CH_4	50 - 75
Carbon Dioxide	CO_2	25 - 50
Nitrogen	N_2	0 - 10
Hydrogen	H_2	0 - 1
Hydrogen Sulfide	H_2S	0 - 3
Oxygen	O_2	0 - 2

Biogas, which is the name given to the initial fermentation product as produced, normally contains between 45 and 55% methane, with the balance being made up primarily of carbon dioxide, as illustrated in Table 3.3. Before it can be used as an automotive fuel, the raw biogas is treated to remove hydrogen sulphide and carbon dioxide, and the methane content is increased to about 90%. The resulting product is usually called biomethane.

Fuel System Description

A typical fuel system for CNG and biogas is illustrated in Figure 3.2. The gas is normally delivered by pipeline to a compressor located at a CNG refuelling outlet that may either be on a public forecourt or in a private refuelling depot.

The more common type of CNG refuelling station is equipped with high pressure (250 bar) storage cylinders that are filled by the compressor. The stored CNG is then used to fill on-board vehicle fuel cylinders to a pressure of 200 bar. This achieves a so called fast fill capability whereby refuelling is completed within 3-4 minutes.

An alternative gas distribution and refuelling configuration is the delivery and storage at the refuelling station of natural gas as LNG. The LNG is then vaporised and compressed into high pressure CNG storage for vehicle refuelling. This so-called liquefied compressed natural gas (LCNG) system relies on the availability of LNG but offers significant economic benefit where such a supply is available.

Dedicated vehicle fleet refuelling facilities are normally located at a private depot where refuelling takes place during periods when vehicles, such as city buses, are out of service (e.g. at night). Such facilities generally have a smaller compressor and less storage capacity than conventional forecourt CNG stations, and therefore are less expensive to purchase and maintain. They usually have one or two fast-fill dispensers and a number of so-called "trickle fill" dispensers that slowly refuel a number of vehicles in parallel over a period of several hours.

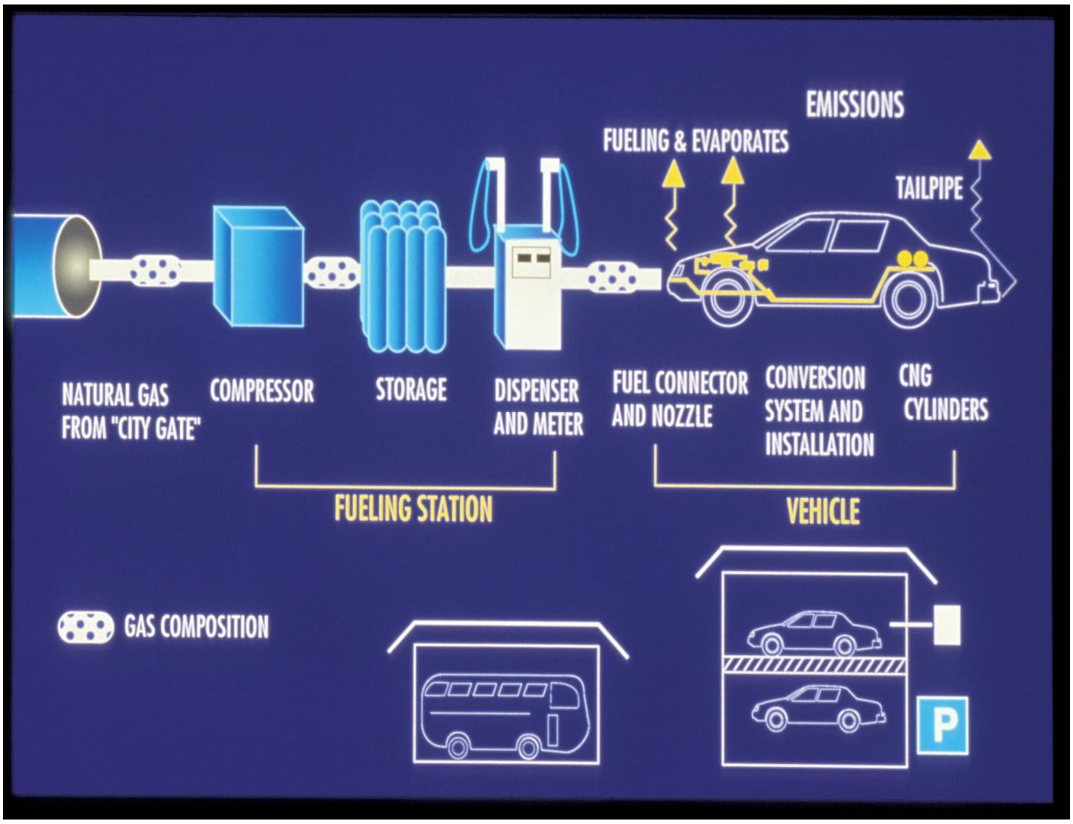

Figure 3.2: CNG Fuel Supply System

In situations where there is no pipeline gas distribution, CNG refuelling can be achieved by using a "mother-daughter" supply system whereby a large "mother" compressor is used to fill a number of CNG storage cylinders mounted on mobile truck or trailer units. The compressed gas is then transported (usually by road) to a "daughter" station where it is used to supply gas to a small compressor for vehicle refuelling. In most cases the mobile storage system is parked close to the daughter compressor and replaced when its gas is used up.

This system of fuel distribution is widely used in India where gas pipeline distribution is still under development.

The modifications required to convert gasoline (spark ignition) and diesel (compression ignition) engines to gas fuelling are quite different. For spark ignition engines, a high pressure CNG fuel cylinder is fitted and connected to a gas regulator mounted in the engine by high pressure gas fuel lines. The regulator reduces the gas pressure in two or three stages so that it can be introduced into the carburettor or fuel injection system at a little above atmospheric pressure.

The total after-market conversion cost is around US$1,000 and engine power is usually around 10% lower than for gasoline fuelling. This is because the engine compression ratio has to be retained at its original value to accommodate the use of gasoline when CNG is not available. If, however, the vehicle is purpose-built and dedicated to CNG fuelling, the compression ratio can be optimised for the higher octane rating of natural gas and vehicle performance is essentially similar to that with gasoline fuelling.

For compression ignition engines, conversion to gas fuelling is significantly more complicated and can cost between US$6,000 and US$10,000, depending on the type of engine involved and the conversion technology employed.

There are basically two common approaches to converting a compression ignition engine to gas fuelling. The first involves retaining the diesel injection system. Natural gas to provide the main engine power is aspirated into the cylinders using either a carburettor or fuel injection system to provide the engine power. The re-programmed diesel system injects just enough diesel to achieve compression ignition. Such a dual fuel (DF) CNG/diesel conversion has the advantage that the vehicle can revert to 100% diesel fuelling if required, so it is particularly suited to locations where there are insufficient CNG refuelling outlets for full time gas operation.

The level of gas substitution that can be achieved by modern dual fuel conversion systems can be in excess of 90%. However, such high substitution levels can only be achieved under optimum speed and load conditions such as can be achieved by an optimised stationary engine.

In practice, vehicle engines operate over a wide range of speed and load so the level of gas substitution can vary from as high as 90% when the engine is operating under optimum conditions to zero when it is idling. The level of gas substitution, therefore, depends primarily on the driving cycle of the vehicle which, in the case of an urban bus, is highly variable and commonly results in gas substitution levels as low as 35-40%. Consequently, very few dual fuel compression ignition vehicles are produced by the Original Equipment Manufacturers (OEMs).

The preferred approach is to change the engine from compression ignition (CI) to spark ignition (SI) operation. This involves removing the diesel injection equipment and replacing it with spark plugs and a distributor or an electronic ignition system with gas fuel injection or carburetion. The engine now operates in an Otto cycle configuration and its torque curve is significantly different from that in compression ignition operation. One characteristic is that the SI gas engine produces approximately 10% more power than its diesel-fuelled CI equivalent.

The main advantage of SI conversion is that the vehicle carries only one fuel and it enables 100% gas fuelling to be achieved in a high compression engine, thereby significantly improving the economics of gas operation. The engine is, however, dedicated and cannot be switched back to diesel operation.

Implementation Experience

The International Association of Natural Gas Vehicles (IANGV) statistics record that at the end of 2008 there were more than 9 million natural gas vehicles (NGVs) in commercial operation worldwide, of which only about 800,000 were in APEC economies. The number of NGVs and refuelling stations in APEC economies are listed in Table 3.4 together with their associated natural gas consumption and annual growth rates over the last 5 years for which data are available. The number of NGVs worldwide is listed in Appendix A. Growth rates of NGV numbers and gas consumption, both worldwide and by region, are illustrated in Figures 3.3 and 3.4 and NGV statistics for the top 25 economies are listed in Table 3.5.

Table 3.4: NGVs Consumption and Growth in APEC Economies (2007)

APEC Economy	Vehicles	Stations	Natural Gas Consumption (PJ/year)	Annual Growth 2006-2009 %
Australia	2,750	146	2.1	10.0
Canada	12,140	101	1.2	0.0
Chile	8,064	15	1.5	16.0
China	400,000	1,260	160.8	72.0
Indonesia	2,453	9	0.6	33.0
Japan	36,345	327	10.1	9.0
Korea	17,123	121	22.5	17.0
Malaysia	40,248	101	3.5	37.0
Mexico	3,037	9	0.3	0.0
New Zealand	281	12	0.0	-13.0
Peru	54,829	56	4.5	200.0
Philippines	36	3	0.0	67.0
Russia	103,000	224	27.9	24.0
Singapore	2,444	3	0.2	707.0
Chinese Taipei	4	1	0.0	0.0
Thailand	127,735	253	23.6	347.0
USA	110,000	816	23.0	7.0
APEC Totals **APEC %**	**920,489** **9.6%**	**3,457** **23.8%**	**282** **25.2%**	
Worldwide	**9,563,274**	**14,550**	**1,119**	

NGVs were first introduced in Italy around 1935 and their use was greatly expanded following the escalation in crude oil prices in 1973. Industry growth advanced rapidly during the 1980s, notably in Argentina, New Zealand, Pakistan and the USA, and later in Bangladesh, Germany, Malaysia and Sweden. Most recently NGV growth has advanced significantly in Brazil, Colombia, Egypt and Thailand.

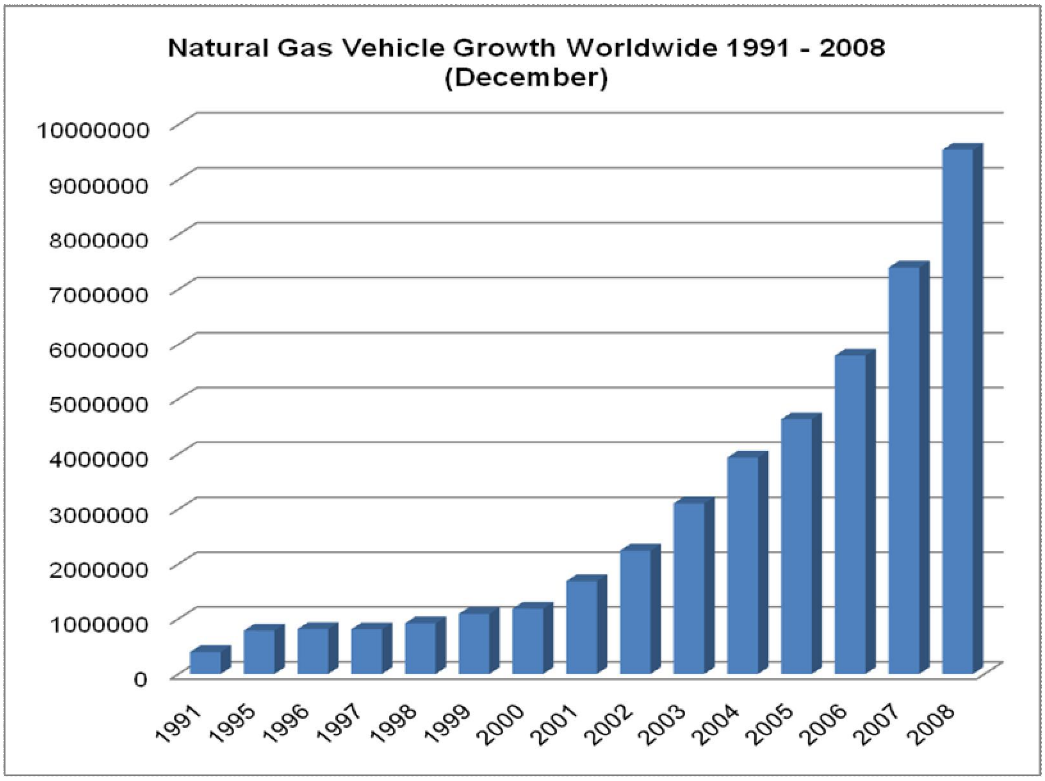

Figure 3.3: NGV Growth Worldwide

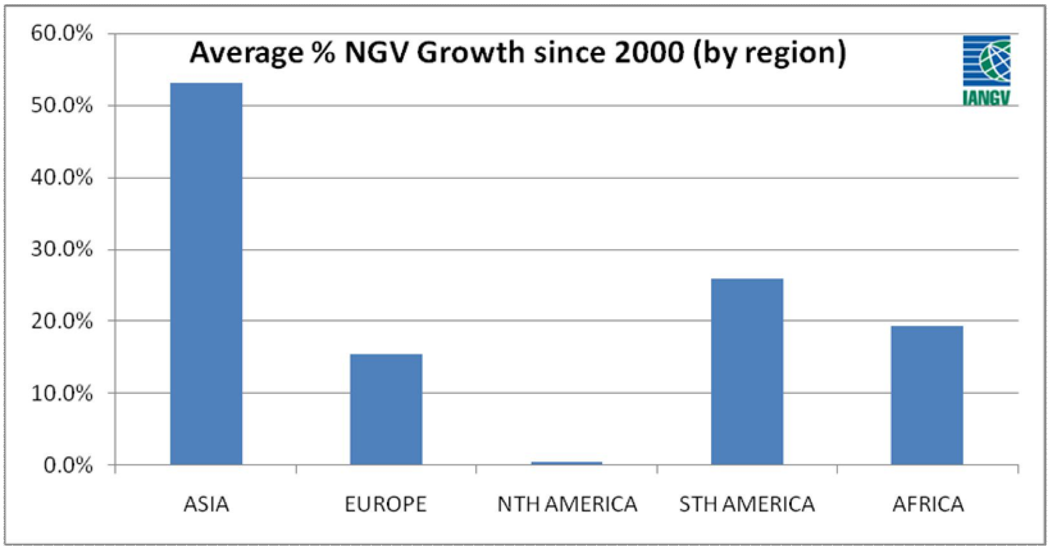

Figure 3.4: NGV Growth since 2000 by Region

Table 3.5: Top NGV Markets Worldwide (2009)

Economy	Vehicles (thousands)	Refuelling sites	Natural Gas Consumption (PJ/year)	Vehicles per Station
Pakistan	2,000	2,600	160.7	769
Argentina	1,746	1,801	142.8	969
Brazil	1,588	1,688	130.0	941
Iran	846	637	77.2	1,328
India	822	325	53.6	2,529
Italy	580	700	50.8	829
China	337	1,260	160.8	267
Colombia	270	401	42.5	673
Bangladesh	180	296	18.2	608
Ukraine	120	224	57.2	536
Thailand	118	253	23.6	465
Armenia	101	214	26.3	474
USA	100	816	22.7	123
Bolivia	100	123	8.2	810
Egypt	99	116	9.8	851
Russia	95	224	27.7	424
Germany	64	804	10.5	80
Bulgaria	60	70	5.2	861
Peru	55	56	4.5	979
Uzbekistan	47	43	3.8	1,093
Malaysia	40	101	3.5	398
Japan	36	327	10.0	109
Myanmar	23	37	25.2	617
Korea	17	121	22.5	142
Sweden	17	122	2.6	139
Canada	12	101	1.2	120
Tajikistan	11	53	0.9	200
France	10	125	3.6	81
Chile	8	15	0.7	538
Rest of the World	62	883	12.7	70
APEC total **APEC %**	**790** **8.3%**	**2,856** **19.6%**	**282** **25.2%**	**Averages** **601**
World Total	**9,563**	**14,536**	**1,119**	**658**

Until quite recently, the extent and rate of NGV penetration in APEC economies has been very much less than in the rest of the world and only 8.7% of all NGVs are currently being operated in APEC economies, although some 21.8% of the refuelling outlets are in APEC economies whose uptake of NGVs is beginning to increase quite rapidly as illustrated in Figure 3.4.

The number of NGVs per refuelling station varies considerably (Table 3.5) and reflects the stage of NGV introduction, the types of NGV used and the level of development of each economy. Thus, refuelling station introduction tends to lag behind NGV demand in the early stages of implementation. Also, a high proportion of the NGVs in Thailand and India, for example, are two- and three-wheelers, which have small gas consumption, whereas refuelling station service is well developed in Canada, Germany, Japan, Korea and the USA where NGVs, such as buses, have higher gas consumption.

The drivers for NGV introduction have been quite varied and include the following:

- Most commonly, NGVs have been introduced in response to high imported oil prices, with the objective of reducing fuel costs through the use of domestic natural gas thereby increasing energy security and reducing overseas expenditure. These have certainly been the drivers in Argentina, Brazil, Egypt, IranIran, Malaysia, New Zealand, Pakistan and Thailand,

- The reduction of urban pollution from automobile exhaust emissions has also been a strong driver in many economies - notably China, India, Korea, Malaysia and the USA – whose governments have provided significant incentives,

- The reduction of GHG emissions has been a driver for NGV introduction in Australia and the EU economies – notably Germany and Sweden.

Possibly one of the most unique drivers for NGV introduction has occurred in India where in order to improve urban air quality the Supreme Court issued an order for the city administration of New Delhi to convert all diesel buses and two-wheelers to CNG fuelling to reduce pollution from exhaust emissions. The results have been spectacular and New Delhi now has cleaner air, although pollution levels are rising again.

Current Status and Outlook

A number of NGV markets are now well established and others are developing rapidly in response to high petroleum fuel prices and the drive towards reduced exhaust pollution and greenhouse gas emissions (GHG).

It can be expected that the present world economic slowdown will also slow the growth of most NGV markets but many are sufficiently firmly established to remain sustainable. It is highly likely that NGV market growth will proceed in response to the anticipated future economic upturn but will probably lag behind until industry confidence returns.

3.2.2 Liquefied Natural Gas (LNG)

Natural gas can also be transported and stored as LNG for use as an alternative transport fuel. Its composition is that of natural gas but it is maintained as a liquid at about –165°C where its volume is approximately 600 times less than in the gaseous state at STP.

Fuel System Description

LNG is not often available for use by the public as an automotive transport fuel. This is because of the rather stringent requirements for its storage both at the refuelling point and on-board the vehicle. LNG is transported by road or rail tanker to the refuelling station, which is normally located in a private company depot, to fuel fleet vehicles operating directly on LNG.

Many LNG stations nowadays include LCNG refuelling to support the operation of existing CNG vehicles. High-pressure piston pumps deliver LNG into atmospheric vaporizers and buffers so that CNG vehicles can be refuelled quickly. An example of such an LNG/LCNG station in California is illustrated in Figure 3.5. This station serves 200 refuse vehicles.

Figure 3.5: Depot Refuelling with 6 LNG Dispensers and 3 LCNG Dispensers

On-board LNG storage consists of one or more super-insulated fuel tanks and the LNG is vaporized during engine operation in a vaporizer heated by the engine cooling system. A pressure regulator controls delivery of gas to the vehicle's engine and maintains a constant pressure.

Apart from the cryogenic fuel storage and vaporiser units, the engine modifications required for LNG Otto cycle and compression ignition engines are the same as those for CNG fuelling.

Implementation Experience

The commercial use of LNG is limited almost exclusively to large fleet vehicles and is particularly well suited to fuel long haul vehicles and those that have high fuel usage. Heavy-duty trucks, buses, refuse vehicles and frequently operated fleet vehicles, such as taxis, are typical vehicles with great potential for LNG fuelling.

Possibly some of the best examples of LNG use in heavy fleet vehicles include the Sainsbury's supermarket delivery vehicles in the UK and similar long haul delivery vehicles in the United States where heavy-duty natural gas engines that can operate on LNG are produced by Caterpillar, Cummins, Detroit Diesel, Mack and Navistar.

In the past, LNG fueling has been limited to situations where there is a readily available source of LNG, as the cost of installing dedicated LNG production facilities (even on a small scale) has not been warranted; however, this situation is changing. The introduction of LNG is probably advancing most rapidly in the United States, aided by an incentive of US6¢ per gallon of gasoline equivalent applicable to alternative transport fuels. This subsidy is enabling the introduction of dedicated small scale LNG production plants.

One successful business model that is emerging is for the LNG production plant owner also to own the LNG refuelling equipment at the client depots and to sell LNG at a price that is always 15% lower than the client would pay for conventional gasoline or diesel.

The main drivers for the implementation of LNG as an alternative transport fuel are essentially the same as for CNG and are primarily economic. The main impediments to widespread implementation of LNG relate to safety considerations associated with cryogenic storage and the handling of the fuel. It seems likely that its use will remain limited to heavy-duty long haul vehicles that use large amounts of fuel and that can benefit from the large amount of fuel storage achievable and the advantages of single or shared depot refuelling.

3.2.3 Autogas (LPG)

LPG is a mixture of propane and butanes and is now called autogas when it is used as a vehicle fuel. Its composition can be in the range from 60-100% propane and 0-40% butane, with the proportion of propane being higher in colder climates (e.g. Canada).

Fuel System Description

Autogas is transported by road or rail tanker to the refuelling station in the same way as conventional gasoline and diesel and is sold on the same forecourt alongside these fuels. The onboard equipment consists of a low pressure fuel tank, fuel delivery lines to a pressure regulator and gas distributor and an engine control module, as illustrated in Figure 3.6.

As is the case with NGVs, most LPG vehicles are capable of operating on either autogas or gasoline. Consequently, full advantage cannot be taken of the higher octane number of autogas. Where compression ignition engines are converted to autogas fuelling, it is common to change them to spark ignition (SI) and Otto cycle operation.

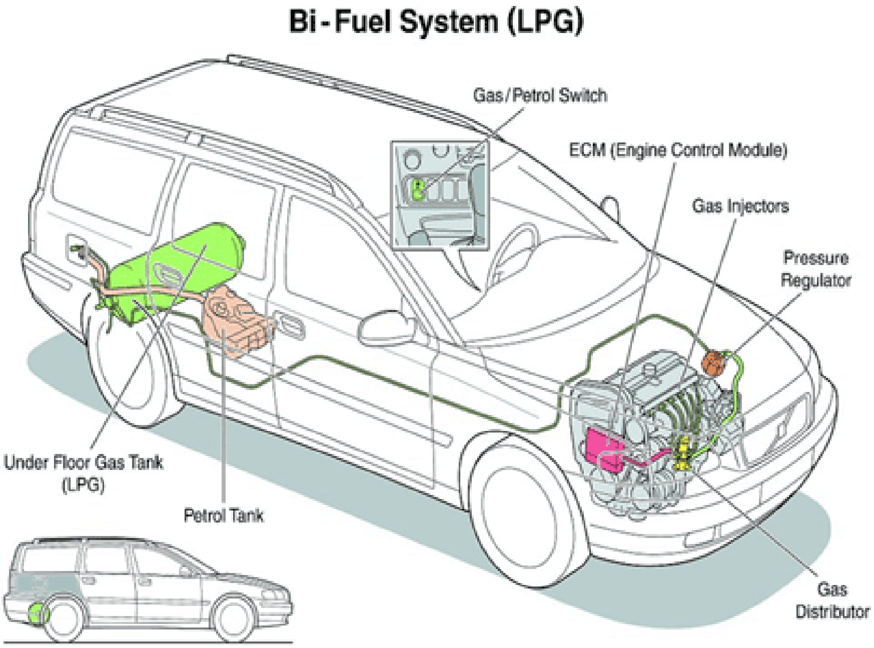

Figure 3.6: LPG Vehicle Fuel System

The cost of autogas supply and infrastructure is generally lower than for other alternative fuels. On an energy-content basis, the cost of bulk LP gas delivered to service stations is roughly comparable to gasoline.

The costs involved in establishing or expanding an autogas distribution network essentially relate to investments in service-station storage and dispensing facilities. The plants and equipment that already exist to handle the importation, production, storage and bulk distribution of LP gas for traditional uses are exactly the same as those used for autogas, although some additional investment may be needed to cope with higher throughput.

Since autogas generally makes use of the existing service-station infrastructure for the distribution of conventional fuels, additional costs for autogas dispensing are low relative to some other alternative fuels. For example, the cost of installing a standard tank, pump and metering equipment for autogas alongside existing gasoline and diesel facilities is typically around a third that of installing dispensing facilities for CNG with the same capacity. This is because of the added cost of dedicated supply pipelines, high-pressure compression, storage cylinders and special dispensers for CNG.

Vehicle conversion costs vary considerably from one country to another, depending on the sophistication and quality of the equipment installed and local labour costs. Conversion costs for older cars with less sophisticated engines tend to be much lower. Worldwide, costs vary from about $500 in developing countries to $3,000 in the United States. The premium for an OEM vehicle is typically at least $1,000 for a light-duty vehicle (LDV).

The make-up of the autogas vehicle fleet by vehicle type differs by country, largely reflecting differences in government policies. In the two largest markets – Korea and Japan – taxis and other light-duty fleet vehicles account for a large share of autogas consumption. In both countries, the overwhelming majority of taxis run on autogas as a result of a combination of incentives and government mandates requiring the use of alternative fuels. In Europe, private cars comprise the main market. In most countries, vehicles that run on autogas are gasoline-powered vehicles that have been converted to use either autogas or gasoline. Korea, where most vehicles are original equipment manufactured (OEM) vehicles, is the main exception.

At present, there are relatively few heavy-duty vehicles (HDV) that run on autogas, since costly alterations to the diesel engine are needed. Most heavy-duty autogas vehicles in operation today are dedicated OEM buses. The municipal bus company in Vienna, which has 550 autogas buses, has the longest and most extensive experience of operating heavy-duty autogas vehicles. The largest autogas bus fleets today are to be found in China. Some delivery trucks fuelled by autogas are operating in some major cities in Australia. Conversion technology is less advanced for diesel vehicles than for gasoline vehicles and diesel conversions are rarely competitive.

Implementation Experience

Autogas is the most widely used and accepted alternative to the conventional oil-based transport fuels, gasoline and diesel, and a number of countries today have well-developed autogas markets. The latest update provided by the World LPG Association, WLPGA (2004) and the IEA (2005) indicate that currently there are more than ten million autogas vehicles in use around the world and more than 40,000 refuelling sites (Table 3.6).

The number of vehicles is growing rapidly, especially in the developing world. As shown in Table 3.7 LPG vehicles in APEC economies account for 42% of the worldwide population and seven of the ten leading autogas consumers are APEC economies. This is in stark contrast to NGVs, for which less than 10% of the market is in APEC economies.

Consumption of autogas worldwide grew at an average rate of 5% in the ten years to 2004, about twice the rate of growth in total LP gas use. The highest rates of growth – and the largest increases in absolute terms – were recorded in Turkey, Poland and Korea. In APEC economies, the average growth rate was 6.2%.

Table 3.6: Largest Autogas Markets (2006)

Economy	Vehicles (thousands)	Refuelling sites	Autogas Consumption (000 tonnes)	Vehicles per Station
Korea	1,723	1,242	3,841	1,387
Poland	1,100	4,500	1,700	244
Australia	492	3,240	1,657	152
Turkey	1,000	4,000	1,570	250
Mexico	450	1,400	1,410	321
Japan	290	1,900	1,307	153
Italy	1,220	2,150	987	567
Thailand (2008)	1,200	355	660	3,380
China	134	285	531	470
Russia	550	470	424	1,170
United States	190	4,300	372	44
Rest of the World	2,401	16,439	3,722	146
APEC total	**3,829**	**12,837**	**9,542**	
APEC %	**40.2%**	**32.2%**	**54.5%**	
World Total	**9,531**	**39,926**	**17,521**	**446**

The oil-price shocks of the 1970s provided the initial impetus for the development of alternative automotive fuels, as countries sought to reduce their dependence on imports of crude oil and refined products. Environmental concerns have since overtaken energy security as the principal driver of government policies to promote such fuels, as they are generally less polluting.

The emergence of autogas as an alternative to gasoline and diesel is the direct result of government policies to address energy security and/or environmental concerns. Until recently, Autogas has been far more successful than any other alternative automotive fuel because of its practical and cost advantages over other fuels. As illustrated in Table 3.5, however, the number of NGVs worldwide is now approaching the number of autogas vehicles and the amount of energy consumed by NGVs is greater than that consumed by autogas vehicles.

In practice, however, converting a vehicle to run on autogas involves some operational inconveniences. The most important of these are the loss of boot/trunk space to accommodate the fuel tank and, in some cases, a marginal loss in acceleration and speed. This inconvenience is offset to some extent by the lower weight of autogas fuel compared to gasoline and the increased flexibility provided by the dual-fuel capability of converted vehicles. Practical experience has shown that vehicle owners are often willing to convert their vehicles to autogas if the savings in running costs are sufficiently attractive.

Safety concerns about the handling and on-board storage of autogas are a barrier to conversion in some cases. A risk assessment study carried out in 1998 by TNO, a Dutch research institute, concluded that the safety of modern autogas vehicles is actually better than for gasoline vehicles. Nonetheless, widely-publicised accidents, often resulting from poor installation, the absence of a safety valve on the fuel-tank or the illegal use of camping gas, have undermined the safety image of autogas in some countries.

Table 3.7: LPG Vehicles: Consumption and Growth in APEC Economies (2006)

Economy	Vehicles (thousands)	Autogas Consumption (000 tonnes)	Annual Growth 2002-2006 %
Australia	492	1,657	5.0
Brunei			
Canada	92	228	-1.3
Chile			
China	134	531	33.1
Hong Kong, China	21	254	13.8
Indonesia			
Japan	290	1,307	-2.3
Korea	1,723	3,841	2.9
Malaysia			
Mexico	450	1,410	2.4
New Zealand	10	29	2.3
PNG			
Peru	6	92	133.3
Philippines		4	
Russia	550	424	18.2
Singapore			
Chinese Taipei			
Thailand	1,200	660	20.1
USA	190	372	3.5
Viet Nam			
APEC Totals	**5,158**	**10,809**	

Current Status and Outlook

Autogas has established itself in many countries as by far the most important alternative fuel because of its favourable mix of inherent practical and cost advantages and environmental benefits compared to gasoline, diesel and other alternative automotive fuels. It is mainly used for light duty vehicles. Airborne emissions of regulated and unregulated toxic gases from autogas use are among the lowest of all the automotive fuels commercially available today.

In addition, GHG emissions from autogas are lower than those from gasoline, diesel and some alternative fuels.

Autogas also has advantages over conventional fuels from an energy security perspective as there is an abundant supply of LP gas from many sources around the world and modern refining processes offer considerable potential for expanding supply to meet increasing demand from the transport sector. LP gas supply is expected to rise briskly in the next few years with growing natural gas production and associated liquids extraction. Field and refinery supplies will also increase as wasteful flaring and venting practices are eradicated.

In addition, there is considerable scope for diverting supplies from relatively low-value petrochemical uses, where LP gas can easily be replaced by other feedstocks such as naphtha, ethane and distillate. The use of gaseous automotive fuels may also enhance energy security in the long term, by paving the way for a hydrogen economy where lessons learned in the handling and use of gas, storage, transportation and safety will be critically important.

3.2.4 Hydrogen

One of the most promising, alternative transportation fuels is hydrogen as it results in zero carbon emissions. It has also been demonstrated that a hydrogen vehicle is capable of replacing conventional fuel without requiring any compromise in dynamic high performance.

Fuel System Description

There are two quite separate approaches currently being pursued for utilising hydrogen as an alternative transport fuel. In both cases, the hydrogen must be stored, both at the refuelling site and on the vehicle, either under high pressure or at low temperature (-253^{o}C).

The first approach is to burn the hydrogen fuel in an internal combustion engine similar to that used by NGVs. For this purpose the hydrogen fuel must be delivered to the engine via a gas pressure regulator or vaporizer, similar in principle to those employed for CNG and LNG.

The second approach is to supply the hydrogen to a hydrogen fuel cell to produce electricity that can then be stored in an on-board battery and used to power an electric motor. In this configuration, the fuel cell is effectively an energy (hydrogen) converter and the vehicle power plant is essentially the same as that of an EV, as discussed further in Section 3.5.1 below.

The use of hydrogen as an alternative transport fuel is still very much at the RD&D stage and cannot, realistically, be claimed to have any implementation track record. Consequently, there is little to be learned from its early use for the purpose of developing the alternative transport fuel implementation guidelines that are the objective of this report.

3.3 Alcohol Fuels

The two alcohol fuels that have been introduced as substitutes for gasoline and diesel are ethanol and methanol. Both have been used extensively as a fuel extender and octane enhancer in low percentage blends with gasoline. Strictly speaking, such use does not qualify as an alternative transport fuel. However, there are some lessons to be learned from the need to reconfigure the fuel distribution, handling and engine systems to accommodate alcohol additives that are miscible with water which, if present, will breakdown the blend.

Both ethanol and methanol can also be utilised in high percentage (55-85%) blends with gasoline, for which considerable engine and vehicle modification is required.

In the following sections, emphasis is placed on high percentage alcohol blends that achieve significant gasoline substitution in an individual vehicle. While considerable research has been conducted on the use of alcohols for diesel substitution, this has not really proceeded beyond the demonstration stage except perhaps in cases where the diesel engine has been modified to spark ignition in Otto cycle operation as for gasoline substitution.

3.3.1 Ethanol

Anhydrous ethanol (containing less than 1% water) can be blended with gasoline in all proportions up to 100% (E100) and most spark ignition gasoline engines available today will operate on blends containing up to 20% ethanol (E20).

Brazil has by far the greatest experience of using ethanol as an alternative transport fuel, as illustrated by the data presented in Table 3.8. Over the years since 1931, the amount of ethanol that has been blended with gasoline in the Brazilian market has varied in response to economic conditions but has gradually increased to the levels indicated in Table 3.9. Blending levels currently employed in APEC economies are listed in Table 3.10.

Table 3.8: Leading Fuel Ethanol Markets

Characteristics	Brazil	Canada	Sweden	USA
Fuel Used	E20 to E100	E85	E85	E85
Main feedstock	Sugar cane	Corn & Wheat	80% imported	Corn
Total FFV fleet	6.2 million	600,000	126,500	7.3 million
FFV % of registered	12%	2.2%	2.9%	2.8%
Refuelling stations	33,000	3	1,200	1,868
EtOH station %	100%	0%	30%	1%

Table 3.9: Ethanol blends in Brazil (1931-2008)

Year	Ethanol Blend	Year	Ethanol Blend
1931	E5	1999	E24
1976	E11	2000	E20
1977	E10	2001	E22
1978	E18-20-23	2002	E24-25
1981	E20-12-20	2003	E20-25
1982	E15	2004	E20
1984-1986	E20-12-20	2005	E22
1987-1988	E22	2006	E20
1989	E18-22-13	2007	E23-25
1992	E13	2008	E25
1993-1998	E22		

Table 3.10: Ethanol Blends Currently on Sale in APEC Economies

Economy	Ethanol
Australia	E10
Brunei Darussalam	n/a
Canada	E5 (Ontario), E7.5 (Saskatchewan), and E8.5 (Manitoba); limited offer of E85
Chile	E5 trials
China	E10 in 5 provinces, 27 cities
Japan	E3
New Zealand	E10 at three Auckland sites
Peru	E7.8 (2010)
The Philippines	E10
Chinese Taipei	E3
Thailand	E10, E20
United States	E10, E85

More recently, ethanol produced from corn has been blended into gasoline and used as an automotive fuel in several Midwestern states of the USA. Today, most cars in the US can operate on blends of up to 10% ethanol (E10). Blends up to E20 can be used in most modern gasoline engines with some re-tuning, although E10 has become the most widely accepted blend in most countries other than Brazil.

While ethanol can be blended with gasoline at all levels up to 100%, the maximum blending amount is usually no greater than 85%, with the balance being made up of gasoline to adjust the Reid Vapour Pressure (RVP) of the fuel to a range closely similar to that of pure gasoline. Some engine and vehicle modifications are required to accommodate E85-100 and dedicated alcohol vehicles have been manufactured in Brazil since 1979, as illustrated by the data listed in Table 3.11.

Dedicated alcohol vehicles are now being superseded by flexible fuel vehicles (FFVs) in both the USA and Brazil (Tables 3.11 and 3.12), and are now entering the market worldwide. FFVs can operate on any fuel mixture ranging from 100% gasoline to 100% ethanol and are thus able to take advantage of the lowest priced fuel available. In most countries this is E85, although the proportion of gasoline may vary with location and season, as does the composition of diesel fuel. In Brazil, some FFVs can also operate on natural gas.

Fuel System Description

Because of its miscibility with water, ethanol fuel distribution, storage and dispensing requires exclusion of water from all handling systems as introduction of more than about 1% of water will result in separation of the ethanol and hydrocarbon components. This requirement involves significant costs as most underground gasoline storage tanks at gasoline refuelling stations leak and usually contain a layer of groundwater underlying the gasoline. Such tanks have to be sealed or replaced so that water is excluded.

In addition many of the components of conventional gasoline engines are not compatible with ethanol and need to be replaced. Examples include synthetic rubber fuel lines, certain alloys, a number of paint types and the Terne plate that lines conventional gasoline and diesel vehicle fuel tanks. Once these technical requirements have been addressed, however, the transportation and handling of ethanol fuels uses essentially the same tankage and equipment as gasoline.

Implementation Experience

Current estimates indicate that there are approximately 20 million alcohol vehicles in operation worldwide, of which 14 million are flexible fuel vehicles, making ethanol the leading alternative transport fuel currently being used. The number of ethanol vehicles manufactured in Brazil and the USA are listed in Tables 3.10 and 3.11, respectively, and show that although the USA is the leading manufacturer, ethanol vehicle penetration is much higher (28.7%) in Brazil.

Table 3.11: Ethanol Vehicles Manufactured in Brazil (1979-2008)

Year	Pure Alcohol (E100)	Flexible Fuel (E20-E100)	Total Light Vehicles	Ethanol Vehicles as % of Total Light
1979	4,614	-	1,022,083	0.5
1980	254,001	-	1,048,692	24.2
1983	590,915	-	854,761	69.1
1986	697,731	-	960,570	72.6
1988	569,189	-	978,519	58.2
1990	83,259	-	847,838	9.8
1993	264,651	-	1,324,665	20.0
1998	1,451	-	1,501,060	0.1
2000	10,106	-	1,596,882	0.6
2002	56,594	-	1,700,146	3.3
2003	34,919	49,264	1,721,841	4.9
2004	51,012	332,507	2,181,131	17.6
2005	51,476	857,899	2,377,453	38.2
2006	775	1,391,636	2,471,224	56.3
2007	3	1,936,853	2,801,011	69.1
October 2008	12,836	2,048,607	2,732,888	75.4
Totals	**5,671,185**	**6,616,766**	**42,753,054**	**28.7%**

Table 3.12: E85 FFVs Manufactured and in Use in the United States (1998 – 2008)

Year	Light-Duty E85 FFVs produced	Light-Duty E85 FFVs increase	Total fleet E85 FFVs in use
1998	261,165	171,422	**171,422**
1999	426,724	357,450	**528,872**
2000	600,832	528,315	**1,057,187**
2001	581,774	533,458	**1,590,645**
2002	834,976	793,575	**2,384,220**
2003	859,261	837,357	**3,221,577**
2004	674,678	670,794	**3,892,371**
2005	735,693	735,693	**4,628,064**
2006	866,194	866,194	**5,494,258**
2007	974,095	974,095	**6,468,353**
Aug-08	793,354	793,354	**7,289,908**

These statistics are, however, somewhat misleading as many of the flexible fuel vehicles currently on the road in the United States are not using fuel ethanol because their owners are often unaware of the flexible fuel capability. A recent survey has indicated that only about 65% of FFVs in the United States are actually using ethanol fuel.

A clearer picture of the degree of ethanol substitution is obtained from consideration of the amounts of fuel ethanol produced and consumed in each of the leading economies as listed in Tables 3.13 and 3.14. These data show that the USA is both the leading producer and consumer of fuel ethanol - all of which is consumed by the domestic transport fuel market.

Table 3.13: Fuel Ethanol Production (2007)

Economy	(million tonnes)
USA	19.31
Brazil	14.91
European Union	1.69
China	1.44
Canada	0.63
Thailand	0.24
Colombia	0.22
India	0.16
Central America	0.12
Australia	0.08
Turkey	0.05
Pakistan	0.03
Peru	0.02
Argentina	0.02
Paraguay	0.01
APEC total	**21.72**
APEC %	**55.79%**
World Total	**38.93**

The rapid growth in the introduction of ethanol as an alternative transport fuel in the United States is further illustrated by the data listed in Table 3.15, which shows the growth in fuel ethanol imports as demand has outstripped domestic production.

The US Energy Policy Act of 2005 mandates a minimum renewable fuel consumption of 4 billion gallons in 2006, increasing to 7.5 billion gallons in 2012; however, production has already exceeded the 2006 target. A federal tax credit of 51¢ per gallon available to ethanol refiners has also contributed to increased ethanol production.

Table 3.14: Alcohol - Consumption in Road Transport (thousands of metric tonnes)

Country	2002	2003	2004	2005	2006	2007	Market %
USA	6,190	8,620	10,490	12,030	15,980	20,580	52.2%
Brazil	4,494	3,893	5,003	5,852	7,341	14,910	37.8%
European Union	331	499	709	1,143	1,812	1,690	4.3%
Canada	266	286	286	340	260	1,440	3.6%
Colombia	28	251	266	286	340	630	1.6%
Central America	60	60	60	77	74	120	0.3%
Australia	0	0	0	22	52	80	0.2%
Paraguay	1	1	0	8	9	10	0.0%
Philippines	0	0	0	0	3	NA	

Table 3.15: U.S. Fuel Ethanol Imports by Source (millions of gallons)

Country	2002	2003	2004	2005	2006	2007
Brazil			90.3	31.2	433.7	188.8
Costa Rica	12	14.7	25.4	33.4	35.9	39.3
El Salvador	4.5	6.9	5.7	23.7	38.5	73.3
Jamaica	29	39.3	36.6	36.3	66.8	75.2
Trinadad & Tobago				10.0	24.8	42.7
Canada						5.4
China						4.5
Total	**45.5**	**60.9**	**159.9**	**135.0**	**653.3**	**426.2**

U.S. trade policy on ethanol includes an ad valorem tariff of 2.5% as well as an import duty of 54¢ per gallon. The tariff is meant to ensure that the benefits of the domestic U.S. ethanol tax credit do not accrue to foreign producers. The other important trade policy that affects ethanol is the Caribbean Basin Recovery Act (CBERA) that groups Central American countries with Caribbean countries. This act defined rules for importing ethanol under the Caribbean Basin Initiative (CBI).

Table 3.16: World Ethanol Production Forecast 2008 - 2012 (millions of gallons)

Economy	2008	2009	2010	2011	2012	Annual Growth %
Brazil	4,988	5,238	5,489	5,739	5,990	2.8
USA	6,198	6,858	7,518	8,178	8,838	5.7
China	1,075	1,101	1,128	1,154	1,181	1.4
India	531	551	571	591	611	2.2
France	285	301	317	333	349	3.2
Spain	163	184	206	227	249	6.9
Germany	319	381	444	506	569	9.7
Canada	230	276	322	368	414	9.9
Indonesia	76	84	92	100	108	5.6
Italy	50	53	55	58	60	2.8
ROW	2,302	2,548	2,794	3,040	3,286	5.7
World	16,217	17,575	18,936	20,294	21,655	4.6

The incentives for ethanol introduction as an alternative transport fuel have been primarily economic – particularly in Brazil and the USA where strong agricultural lobbies have shaped government policy. Additional drivers have included reduced exhaust emissions, increased energy security and the political capital gained from pursuing so-called "green policies".

Quite recently, however, ethanol transport fuel substitution has experienced several setbacks because:

- Evidence is emerging that ethanol production and use may result in a negative energy balance,
- The net GHG emission footprint is now thought to be significantly greater than originally suggested,
- A number of economies are having to import fuel ethanol, thereby reducing their energy self sufficiency rather than increasing it,
- There is now strong evidence that the diversion of agricultural land to biofuel production is having a significant and adverse impact on world food prices.

While the above impediments are still being debated, they are likely to influence government thinking in many economies. Indeed some APEC economies (notably New Zealand) have already repealed their biofuel mandates.

Current Status and Outlook

The introduction of flexible fuel vehicles has made a promising start and is likely to continue, although future growth will be significantly influenced by the extent to which the impediments listed above can be accommodated.

Fuel ethanol accounts for some 90% of total ethanol production in most economies and is projected to increase this market share. Meanwhile, total world ethanol production is forecast to grow by nearly 5% per year through 2012, as illustrated by Table 3.16 which shows that Canada is forecast to achieve the highest growth rate among APEC economies.

3.3.2 Methanol

As in the case of ethanol, methanol can be blended with gasoline in all proportions up to 100% (M100), but is more susceptible to phase separation in the presence of water due to its greater polarity than ethanol.

Methanol has been extensively used as a gasoline extender and octane enhancer in low percentage (M2-3) blends and can be used in blends up to M15 without engine modification. However, great care must be taken to exclude water and it is normal to include a co-solvent, such as a higher alcohol like isobutanol, to stabilise the blend and prevent phase separation.

High methanol blends require some engine modification but can be used in modern FFVs. The most common blend composition is M85, which is required to achieve a suitable Reid Vapour Pressure for ease of cold starting.

Fuel System Description

The requirements for methanol storage, distribution and handling are essentially similar to those for ethanol listed above. The main differences are that low methanol blends are more susceptible to phase separation in the present of moisture at levels as low as 0.1% and methanol is intrinsically more toxic than ethanol.

The toxicity issue is of concern because an M85 blend has extremely powerful solvent properties and is capable of rapid absorption through the skin.

Otherwise the engine modification requirements for fuel methanol are essentially similar to those for ethanol.

Implementation Experience

A number of demonstration trials of M15 and M85 vehicles have been carried out in several countries, notably New Zealand and the United States, and these have shown that there are no insurmountable technical barriers to the introduction of either fuel. At this time, however, the commercial use of methanol as an alternative transport fuel is not being pursued so the only implementation experience available is from demonstrations.

Current Status and Outlook

It seems unlikely that methanol will be widely used as an alternative transport fuel in the foreseeable future. Interest is, however, becoming focussed on methanol fuel cells in which methanol is first converted to hydrogen and used in a solid polymer fuel cell (SPFC) to produce electricity for vehicle propulsion. This application, while potentially attractive, is still at the research stage.

3.4 System Compatible Fuels (Biodiesel, Unconventional Hydrocarbon Fuels)

Biodiesel and Synthetic Hydrocarbon (SHC) fuels are closely compatible with conventional hydrocarbon fuels such as diesel so both can substitute for, and be blended with, petroleum derived gasoline and diesel.

3.4.1 Biodiesel

For the purpose of this report, biodiesel refers to a non-petroleum-based fuel consisting of long chain alkyl (usually methyl) esters which can be used either alone, or blended with conventional diesel, in unmodified compression ignition engine vehicles. It does not include vegetable oils and animal fats that have not been esterified, as these have not been introduced into the commercial market.

Fuel System Description

A variety of vegetable oils, animal fats and algae can be used to produce biodiesel. These are listed, together with their characteristics, in Table 3.17.

Pure biodiesel (B100) can be used to fuel most compression ignition engines, but is usually blended with conventional petroleum-based diesel. Blends of 20% biodiesel with 80% petroleum diesel (B20) can generally be used in unmodified engines but some engine modifications may be required for higher blend levels to avoid maintenance and performance problems.

Blending can be achieved by:

- Mixing in tanks at the point of manufacture,
- In-line mixing while filling the tanker,

- Motion mixing in the delivery tanker.

Otherwise, the distribution, storage, dispensing and vehicle end-use of biodiesel uses the same technology and equipment as employed for conventional diesel.

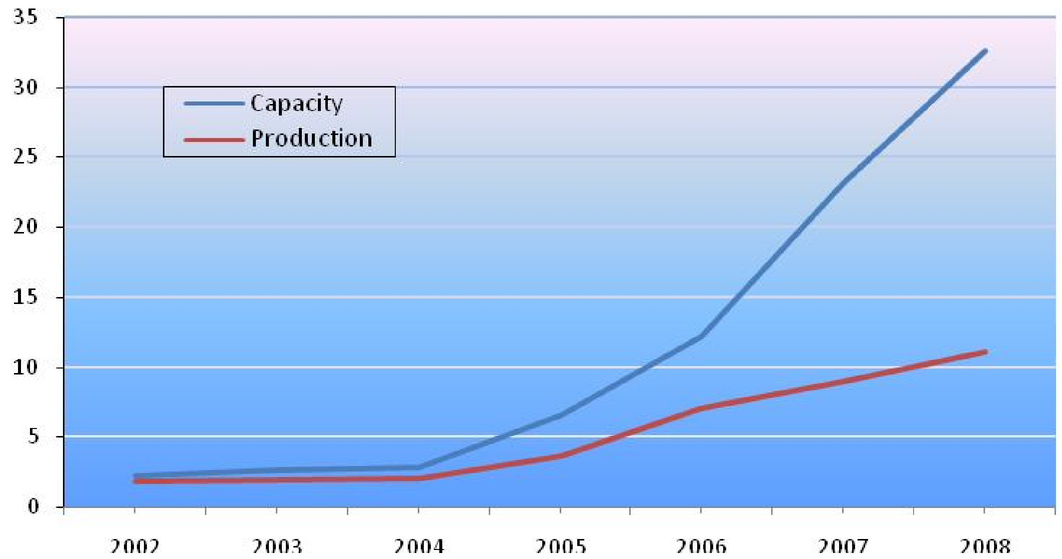

Figure 3.7: World Biodiesel Production and Production Capacity (million tonnes).

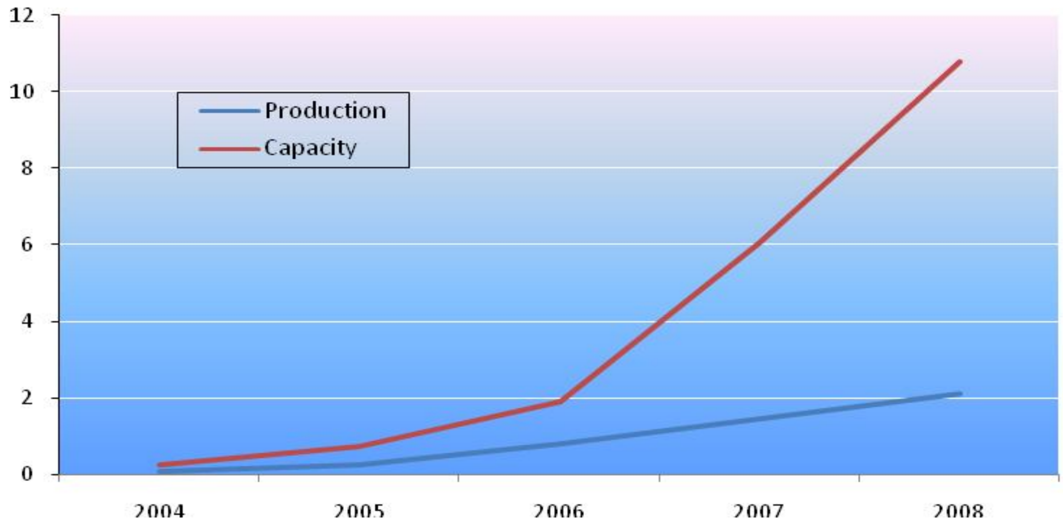

Figure 3.8: US Biodiesel Production and Production Capacity (million tonnes)

Table 3.17: Potential Biodiesel Feedstocks

Biodiesel Feedstocks	Comments
Vegetable Oils	
Castor Oil	Currently used as a food additive and for medicinal purposes
Coconut (Copra) Oil	Widely available in tropical regions
Corn (Maize) Oil	Widely available from large Maize plantings
Cottonseed Oil	Not currently cost competitive
False Flax Oil	Historically used in oil lamps in Europe
Hemp Oil	Low emissions but a problem due to Maruijana association
Jatropha Oil	A strong prospect for growth on marginal lands
Mustard Oil	Comparable to Canola oil as a Biodiesel
Palm Oil	Widely grown in Malaysia but competition from food uses
Peanut Oil	Used in early biodiesel trials
Radish Oil	Contains up to 48% extractable oil
Rapeseed (Canola) Oil	Most commonly used for Biodiesel production in Europe
Ramtil Oil	Used for lighting in India
Rice bran Oil	Widely grown in Asia and low cost
Safflower Oil	Subject of several Biodiesel trials
Salicornia oil,	Native to Mexico, thrives in salty soils
Soyabean Oil	Widely produced for food use. Fuel use not currently economic
Sunflower Oil	Suitable for Biodiesel but not currently economic
Tung Oil	Suitable for Biodiesel but not currently economic
Waste Cooking Oils	Widely used for Biodiesel production in several APEC economies
Animal Fats	
Sheep & Beef Tallow	Main source of Biodiesel in Australia and New Zealand
Chicken Fat	Not currently used but suitable as a Biodiesel
Algae	
Algae Oils	High yield and does not displace land for food crops
Halophyte Oils	Yields equal to Soyabens and grown in salt water

Implementation Experience

Biodiesel production capacity is growing rapidly but actual production is lagging well behind both worldwide and in the United States, which has the largest biodiesel production capacity, as illustrated in Figures 3.7 and 3.8. Europe is currently the largest biodiesel producer. Today, there are approximately 120 biodiesel production plants in the EU producing up to 6,100,000 tonnes of biodiesel annually. These plants are mainly located in Germany, Italy, Austria, France and Sweden.

In the United States, there are at least 25,000 fleet vehicles and 560 outlets that supply biodiesel ranging from B2 to B100, with B5 – B20 being the most common. The biodiesel blends currently sold in APEC economies are listed in Table 3.18.

Table 3.18: Biodiesel Blends Currently Sold in APEC Economies

Economy	Biodiesel
Australia	B2 to B100
Canada	B2, B5 and B20
Chile	B5 trials
China	B5, B10 (2020)
Indonesia	B2.5, B5
Japan	B5
Korea	B5, B20
Malaysia	Envo Diesel - B5
New Zealand	B5
Papua New Guinea	SVO at different blend levels
Peru	B2 (2009), B5 (2011)
The Philippines	B1
Chinese Taipei	B1 to B20
Thailand	B2, B5
United States	B2, B5, B20, B100

Current Status and Outlook

The use of biodiesel as an alternative transport fuel is attractive because of its ease of introduction into the fuel market and the plentiful capacity both worldwide and in several APEC economies for market growth.

Currently, however, market growth is inhibited by economic factors and concerns that the production of biodiesel feedstocks will compete with food crop production. Even if these concerns are overcome, biodiesel will make only a small contribution to meeting the diesel demand in most APEC economies until such time as its production from algae becomes a commercial reality.

3.4.2 Synthetic Gasoline and Diesel

Synthetic gasoline and diesel are produced primarily from coal or natural gas via the production of synthesis gas (a mixture of carbon monoxide and hydrogen). Synthesis gas can then be converted to synthetic gasoline and diesel using Fischer-Tropsch technology or to synthetic gasoline via methanol using the Mobil methanol-to-gasoline (MTG) process. Both of these pathways are, or have been, in commercial production and the gasoline and diesel products are now superior in quality to those produced from crude oil.

Synthetic gasoline and diesel can also be produced from methanol via the Mobil methanol-to-olefins-gasoline-and-diesel (MOGD) process, but this has not yet achieved full commercial realisation.

Fuel System Description

Synthetic gasoline and diesel are closely similar to their conventional petroleum counterparts and can be stored, handled, distributed, dispensed and used to fuel vehicles in the same way and using the same systems and equipment. These fuels can be used directly but are normally blended with petroleum gasoline or diesel and the end user is not normally aware that a synthetic fuel is being used.

Implementation Experience

Full scale synthesis of gasoline and diesel via the Fischer-Tropsch process first occurred in Germany during the Second World War (1939 – 1945) and coal (mainly lignite) was used as feedstock for thirteen coal-to-liquids (CTL) plants mostly located in what later became East Germany. Since the ultimate driver was the need to fuel the war effort, little can be learned from this experience relative to peacetime implementation.

The technology was next employed by South Africa during a period when that country was facing international trade embargos because of its human rights policies. Again, Fischer-Tropsch synthesis was employed to convert coal into gasoline, diesel and a variety of hydrocarbon products by the South African Company SASOL (the Afrikaans acronym for Suid-Afrikaanse Steenkool en Olie - South African Coal and Oil).

SASOL's original CTL pilot plant at Sasolburg was commissioned in 1955. It was subsequently converted into a gas-to-liquids (GTL) facility and is still in operation today. SASOL now operates two CTL plants at Secunda, with a combined capacity of 150,000 bbl/d. In the early 1990s, at the request of the South African government, SASOL licensed a GTL process to PetroSA, the South African state-owned oil company. A PetroSA GTL plant in Mossel Bay has a capacity of 35,000 bbl/day.

Other companies that have developed commercial CTL or GTL processes include Shell, which operates a GTL plant in conjunction with its refinery at Bintulu in Malaysia. There are also a number of CTL or GTL plants planned or under construction, primarily in the United States, China and the Middle East. The largest of these is a GTL plant recently commissioned by Oryx and producing 34,000 bbl/d of synthetic transport fuel rising to 100,000 bbl/d.

The first and only commercial scale GTL plant using Mobil MTG technology was commissioned at Motonui in New Zealand in 1985 and operated effectively for ten years until the MTG section was shutdown. The plant still operates as a methanol production plant. The plant has a raw methanol production capacity of around 4,400 tonnes/day, which was converted to about 2,000 tonnes/day of 93 RON lead free synthetic gasoline. This production was originally slated for blending into the New Zealand gasoline pool. However, its value as a blendstock resulted in almost all of it being exported to overseas refineries.

Current Status and Outlook

As of mid-2008, there were approximately 60 CTL and GTL plants worldwide at various stages of implementation between proposal and operation. Most are in the early stages, as illustrated in Figure 3.9 which shows that about 80% are located in five APEC economies.

The production of synthetic gasoline and diesel currently has a crude oil parity price equivalence of US$45 to 65/bbl and it is to be expected that these plants will proceed as international oil prices recover to levels around US$70 to 80/bbl.

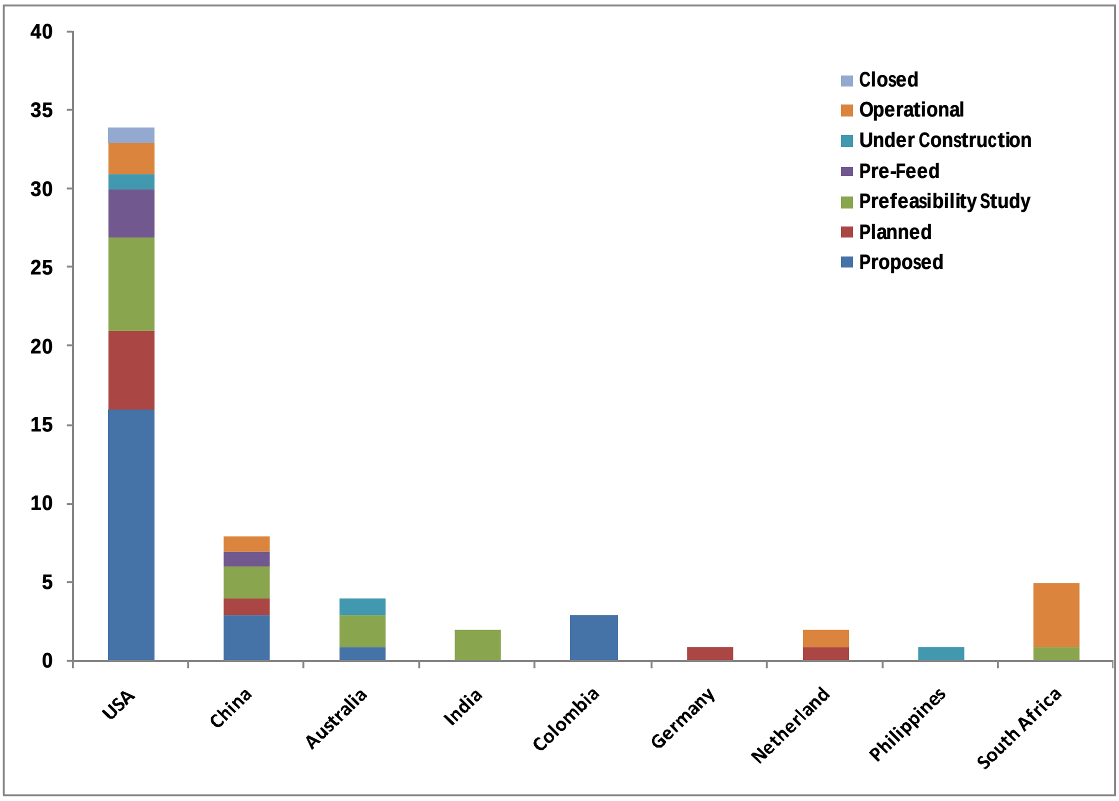

Figure 3.9: CTL and GTL Plants Worldwide (mid-2008)

3.5 Electricity

Electricity has been used to power transport since the late 1800s and its major applications included railways, trolley buses, trams and submarines, as well as road vehicles. These large scale uses of electricity (e.g. mains-connected trolley buses and trams) lie outside the intended scope of this project and are therefore not considered further.

Although the use of electricity to power road vehicles commenced in the late 1890s, the need for longer range autonomy, which battery powered vehicles could not provide, meant that they had effectively disappeared by 1935. Electric Vehicles (EVs) reemerged in the 1960s and 1970s in response to requirements for reducing automobile exhaust emissions.

Three types of hybrid and electric vehicles are considered herein. These are:

- Hybrid electric vehicles (HEVs),
- Battery powered electric vehicles (EVs),
- Fuel cell powered vehicles (FCV).

Fuel System Description

Battery operated electric vehicles (EVs) work by storing electricity from the grid in a large battery that is used to power an electric motor that drives the wheels. EVs operate with zero vehicular emissions and very low noise. Their range is shorter than for conventional vehicles, but is sufficient for most commuter trips and well suited to two-wheelers, which are widely used in China and Chinese Taipei.

HEVs have a conventional gasoline or diesel engine as well as a large battery and an electric motor so the wheels can be driven both by an internal combustion engine and the electric motor. There are various arrangements of these two motors but this configuration is most common for LDVs. The battery is charged by the internal combustion engine and/or by the frictional energy during braking. HEVs have a limited range of battery only operation with zero tailpipe emissions but this can be extended by mounting larger batteries and/or by plugging into the electricity grid when the vehicle is parked (plug-hybrid electric vehicle – PHEV).

FCVs are still in an early stage of development. Most commonly they utilise a hydrogen fuel cell that generates electricity that is stored in an on-board battery and used to power an electric motor. FCVs emit only water vapour and they have the potential to be energy efficient. While there are several small demonstration fleets currently in operation, FCVs are not considered likely to gain a significant share of the road vehicle fleet in any economy before at least 2015 and are therefore not considered further for the purposes of this report.

Implementation Experience

Worldwide there are estimated to be about 115 million EVs, the great majority of which are two-wheelers (e-bikes, e-scooters and electric power-assisted bicycles) mainly in China, and about four million four-wheeled EVs and HEVs mainly in the United States (Table 3.19). Both EVs and HEVs have increased in numbers over the last five years, although they still have only a very small market share. The significant growth in HEV sales in the United States is illustrated in Figure 3.10, where the 2007 market share of 2.2% is expected to triple by 2012.

Table 3.19: Hybrid (HEV) and Electric (EV) Vehicles in Leading User Economies

Year	2004		2005		2006		2007	
Vehicle Type	EV	HEV	EV	HEV	EV	HEV	EV	HEV
Austria	515	0	517	75	1,300	75	NA	NA
Belgium	60	131	50	602	50	1,493	0	2,665
Canada	-	3,000	-	6,000	-	13,500	21	25,783
China	13,000,000	n/a	23,000,000	n/a	33,000,000	n/a	45,000,000	n/a
Denmark	5,300	15	5,650	35	5,650	60	10,650	100
Finland	-	-	-	-	-	-	104	300
France	11,013	650	11,000	3,650	11,000	10,000	NA	NA
Italy	113,201	720	132,491	1,112	145,300	2,170	NA	3,467
Japan	n/a	120,000	n/a	150,000	n/a	260,000	n/a	n/a
Netherlands	500	2,000	500	3,000	500	7,500	500	12,000
Spain	-	-	-	-	-	-	220	10,300
Sweden	400	1,350	360	3,300	320	6,100	314	9,466
Switzerland	10,780	1,057	13,140	2,469	17,590	4,722	23,400	7,762
Chinese Taipei	75,000	n/a	94,000	n/a	100,000	n/a	106,000	n/a
United States	55,852	197,490	68,000	403,366	76,200	655,230	120,000	1,006,301
APEC totals APEC %	13,130,852 98.90%	320,490 98.20%	23,162,000 99.30%	559,366 97.50%	33,176,200 99.50%	928,730 96.70%	45,226,021 99.90%	1,032,084 95.70%
Totals	13,272,621	326,413	23,325,708	573,609	33,357,910	960,850	45,261,209	1,078,144

In spite of the advantages that HEV and EV can bring to their users and their possible contributions to the achievement of governmental objectives, their market share is still small. There are a number of reasons for this, most of which are common to many other alternative transport fuels.

There is still a lack of public awareness regarding alternatives to conventional gasoline and diesel vehicles. Three major hurdles exist for vehicle buyers:

- For a large proportion of the vehicle-buying public, purchase price is the most important criterion when choosing a vehicle. The general public is not aware of the vehicle life cycle costs and how these costs compare among different propulsion alternatives. Because of the higher price of HEV and EV (currently about US$5,000 for a four-wheeled vehicle) most buyers choose a conventional vehicle,

- The range of EVs is perceived as being too small, even though it would be sufficient for the majority of vehicle trips,

- As a result of past battery problems, in certain markets there is a lack of confidence in electric powered vehicles, despite the fact that these problems have been successfully eliminated.

One problem that has been encountered in the introduction of two-wheeled EVs in Chinese Taipei is access to electricity outlets for battery recharging. This is because most owners of electric two-wheelers live in high rise apartments and cannot readily access their own electricity supplies.

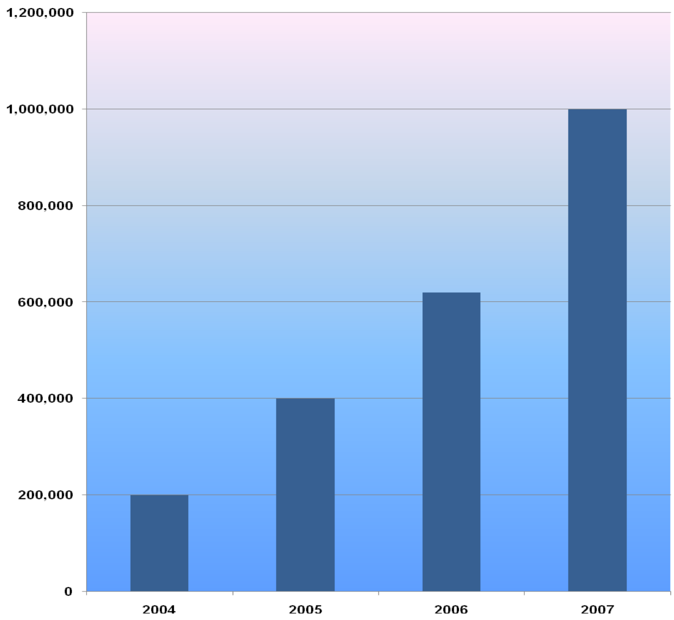

Figure 3.10: Hybrid Vehicle Fleet Size Growth in the United States

HEV and EV are significantly different from conventional vehicles. This means that vehicle manufacturers have to break new ground in terms of vehicle components, drivetrain systems, production facilities, safety issues and vehicle maintenance infrastructure.

- As for any new technology, standardization of HEV and EV components and test methods is not as mature as for conventional vehicles. There is, therefore, a barrier for industry in building up an efficient profit chain.

- Because it takes time to develop new vehicles and to build the production and maintenance infrastructure, manufacturers are not always able to supply sufficient numbers of vehicles to meet the demand of surging markets.

Utilities that generate electricity from intermittent renewable energy resources such as wind and solar have a significant interest in plug-in hybrid electric vehicles (PHEVs and EVs) because the batteries in these vehicles can provide a storage buffer for short term electricity surpluses. However, there are still some technical problems and safety issues to be overcome before large numbers of PHEVs can be used for this purpose.

Current Status and Outlook

The market for battery electric cars and battery electric HDVs is small. However, sales of e-bikes, e-scooters and electric power-assisted bicycles are surging and this trend might continue. Acceptance of EVs in the two-wheeler market might prepare the market for advanced purpose designed EVs such as the Th!nk.

There are a few manufacturers still making specialized EVs. However, there are no LDVs being produced by the major auto manufacturers. Some manufacturers (e.g. Mitsubishi) produce neighborhood electric vehicles (NEVs) that use battery technology and are often used in limited on-road fleet applications.

Today, the share of HEVs in car sales is small. It is below 1% in, for example, Austria, Belgium, Denmark and the Netherlands, about 1.1% in Sweden and 2.2% in the United States. The number of HEV car models available on the market is expected to grow substantially until 2015 and this will boost the HEV sales (Table 3.20). The global market for hybrid vehicles could more than triple by 2012, compared to 2007 sales. Important factors expected to influence the eventual 2015 HEV market share are:

- Regulatory and other governmental measures to overcome the barriers for large deployment of HEVs and EVs,

- The difference in purchase price between HEVs and standard vehicles (HEVs are likely to remain more expensive),

- The quantity of HEVs that manufacturers will be able to supply.

Although the impact of these factors is not yet known, the HEV percentage share of the 2015 car market is expected to remain within the single digits.

Table 3.20: Recent and Forecast Growth of EV and HEV Numbers in the United States

Date	Vehicle Sales	Market Share %	Number of Models
2000	10,000		2
2004	88,000	0.52	8
2005	212,000	1.19	11
2006	260,000	1.53	17
2012	**780,000**	**4.20**	**52**

There are several light-duty HEVs available for purchase today. They include cars, trucks, and even sport utility vehicles. In the United States, hybrids qualify for tax incentives and can be comparably priced to other conventional vehicles. In addition, there are several options for purchasing heavy-duty HEV buses, trucks, and shuttles.

The development and deployment of heavy-duty HEVs is lagging behind those of the light-duty sector. Trucks and buses – with a few commercial exceptions – are in the prototype and demonstration phase today and their fleet share in 2015 is expected to be small.

3.6 Summary

It is apparent from the foregoing overview that there is considerable experience worldwide in the introduction of alternative transport fuels. Much of this experience lies within the APEC economies.

The following points can be noted in summary:

1. Those alternative transport fuels that have achieved significant market penetration and are now in everyday commercial use are listed in Table 3.21. Some initial implementation experience has also been gained for some of the other alternative fuels considered but most of these are still in the RD&D phases and have not yet achieved a level of sustainability in commercial operation.

2. In terms of both vehicle numbers and annual fuel consumption, Table 3.21 shows that autogas and ethanol have achieved quite comparable levels of market penetration both worldwide and in APEC economies. The highest fuel consumption is achieved by NGVs, most of which are in non-APEC economies. Care should be taken in drawing conclusions from these data because:

- There are large numbers of natural gas fuelled motor cycles that do not appear to be included in the vehicle numbers but are included in terms of fuel consumption,

- Those fuels that can be used in both high and low percentage blends, such as ethanol and biodiesel, are probably not well represented by the vehicle numbers listed as they refer only to the numbers of vehicles capable of utilising high percentage ethanol blends. Some of these do not operate on ethanol at all while many others use low blends up to E10, which, while included in the total fuel consumption, are not recorded in Table 3.20. Similarly, the number of vehicles operating on some level of biodiesel or synthetic hydrocarbon blends is not really known,

- EVs, as listed in Table 3.21, are largely comprised of battery operated cycles in China and Chinese Taipei.

Table 3.21: Leading Alternative Transport Fuels Currently in Use

	Vehicle Numbers			Fuel Consumption (PJ/year)			Year
Alternative Fuel	Worldwide (000)	APEC (000)	APEC %	Worldwide	APEC	APEC %	
Gaseous Fuels							
CNG/LNG/Biomethane	9,076	790	8.7	1,119	280	25.0	2,008
Autogas (LPG)	9,531	3,829	40.2	871	474	54.5	2,006
Alcohols							
Ethanol	14,706	7,576	51.5	828	459	55.4	2,007
System Compatable Fuels							
Biodiesel				361	135	37.4	2,008
Synthetic hydrocarbons				355	0	0.0	2,007
Electricity							
Battery Electric Vehicles	45,261	45,226	99.9	109	109	99.9	2,007
Hybrid Electric Vehicles	1,078	1,032	95.7	8	7	95.7	2,007
Totals	**79,652**	**58,453**	**59.2%**	**3,650**	**1,464**	**52.6%**	

3. The main drivers for using alternative transport fuels are somewhat different for the different stakeholders:

- Governments are driven mainly by energy security and GHG emission considerations,

- Local authorities are driven largely by concerns about local air quality and the reduced exhaust emissions achieved by many alternative fuels,

- Alternative fuel industry operators are driven primarily by economics and respond particularly to financial incentives offered by government,

- Alternative transport fuel consumers are driven primarily by the lower costs involved and to some extent by the reduced exhaust emissions and/or renewable nature of the fuels.

4. Several impediments to the introduction of alternative transport fuels have been identified. These include:

   - Inadequate fuel supply and refuelling infrastructure. This is of little or no concern for those fuels that can utilise the existing fuel distribution infrastructure but becomes progressively more important as modifications to the fuel delivery system or its replacement are required,

   - Access to refuelling infrastructure can also represent a significant, though different type of impediment as evidenced by the access to electrical outlets for battery recharging in EVs,

   - The development of fuel use and safety regulations together with establishment of industry standards and codes of practice can be quite time consuming and can impede industry development,

   - Additional costs associated with the purchase or conversion of an alternative fuel vehicle is usually a significant barrier to the introduction of alternative fuels and must usually be overcome by the application of government or industry incentives,

   - Lack, or loss, of public confidence in an alternative fuel has, in some cases, strongly inhibited its introduction and in almost all cases some form of public awareness campaign is required to achieve acceptance.

4. Implementation Policies

The oil-price shocks of the 1970s provided the initial impetus for the development of alternative automotive fuels, as countries sought to reduce their dependence on imports of crude oil and refined products. Environmental concerns have since overtaken energy security as the principal driver of government policies to promote such fuels, which are generally less polluting.

The focus of environmental policy action has been air pollution in major cities, which is caused mainly by automotive fuels. Since the 1990s, attention has shifted to the threat of global climate change due to rising concentrations of GHGs in the atmosphere resulting primarily from the burning of fossil fuels. As a result, governments are looking to fuels that emit less carbon dioxide (CO_2), methane (CH_4) and NO_2, which are the main GHGs resulting from energy use.

As an absolute minimum, governments must establish an appropriate regulatory environment and institutional infrastructure to support the introduction of alternative transport fuels. In reality, however, governments usually need to assist in overcoming the initial cost barriers associated with the introduction of new technology and infrastructure.

There are numerous options for policies and actions to promote alternative transport fuels, as illustrated in Table 4.1. These are discussed as follows:

4.1 Financial Incentives

Incentives can be designed to encourage or discourage certain actions or behaviours. Tax policy is a good opportunity to ensure that, at least in the early years of market development, alternative fuels can be priced competitively with gasoline and diesel, based upon their clean burning characteristics. Tax relief for clean fuels versus traditional fuels would help maintain a comparative price advantage. Such a price advantage is probably the most important element for market success.

Financial, or market-based, incentives can relate to the fuel, the vehicle or the vehicle use. Taxation is the most cross-cutting and can be applied in the forms of a subsidy, a tax exemption or a penalty, as listed in Table 4.1.

The financial incentives listed in Table 4.1 are demand-side fiscal measures aimed directly at reducing the cost to the end user of switching to an alternative fuel. Supply-side fiscal measures that reduce the tax liability of fuel providers and/or vehicle manufacturers can also lower these costs in an indirect way.

For example, profit-tax credits can be used to encourage OEMs to develop and market dedicated AFVs and to encourage fuel providers to invest in distribution infrastructure.

Table 4.1: Policies and Measures to Promote Alternative Transport Fuels

Fiscal/financial	Regulatory	Other
Fuel tax exemption or rebate	Mandated sales/purchase for fleet vehicles (enforced)	Government vehicles use alternative transport fuels
Road/registration-tax exemption or rebate	Harmonised refueling facility standards and codes	Information dissemination; public awareness campaigns
Vehicle sales-tax exemption or income/profit tax credit (purchasers and OEMs)	Vehicle conversion standards and industry codes of practice	Voluntary agreements with OEMs to develop and market alternative fuelled vehicles
Investment tax credits for distribution infrastructure and R&D	Health and safety regulations	Direct R,D & D funding for alternative fuelled vehicles and technology
Grants/tax credits for vehicle conversion/acquisition	Exemptions from vehicle use restrictions	
Rapid depreciation for commercial vehicles and distribution infrastructure		
Parking/Road User charge exemptions		

4.1.1 Fuel Taxes

Fuel taxes are the main measure that most economies use to promote alternative fuels. They can involve a lower rate of excise duty (and/or sales tax) or its complete exemption. In some cases, commercial vehicles may enjoy a rebate on fuel taxes. These measures reduce the payback period for converting or acquiring an AFV and are also highly visible so they raise public awareness of the potential cost savings from using alternative fuels.

4.1.2 Vehicle Taxes

The most common way of providing incentives for vehicles themselves is to subsidise the higher cost of buying an OEM vehicle or the cost of converting an existing conventional fuel vehicle. Subsidies are most easily provided through grants or tax credits. In this regard it should be noted that tax *credits* and tax *deductions* differ considerably in terms of the benefits that are received and thus the incentive delivered.

In some cases eligibility may be dependent on the emission performance of the vehicle being converted. AFV purchases or conversions can also be encouraged directly through partial or complete sales or consumption-tax exemptions. Lower rates or exemptions from vehicle registration and/or annual road taxes are another approach. In most cases, these incentives apply for a specified time to limit the loss of tax revenue and the "free-rider problem" (where the financial benefit to some end users from the tax incentive is greater than is necessary for them to switch to using an alternative fuel).

4.1.3 Vehicle Use Taxes

AFVs can be made more attractive by the application of taxes to their actual use. Most commonly this involves the reduction of, or exemption from, one or more of the following costs:

- Road user charges,
- Road tolls,
- Parking costs and access to 'no wait' taxi zones at airports and train stations (Göteborg and other Swedish cities),
- 'Bad-air' day traffic bans or limitations (Milan, Paris, etc.),
- Congestion charges and access to carpool lanes (USA),
- Participation in emissions trading schemes (ETS) in Europe.

4.2 Regulatory Actions

Governments can strongly influence how quickly alternative fuels and technologies are adopted through the appropriate design of a regulatory framework and there is a range of policies and measures currently employed to promote the use of alternative fuels.

The most direct form of regulatory measure is the use of legal mandates on public or private organisations to sell or purchase AFVs. Traffic-control regulations can also be used to favour such vehicles. For example, AFVs may be granted exemptions from city or highway-driving restrictions, such as those imposed on peak-pollution days.

Government must also be responsible for the development of coherent regulations, standards and industry codes of practice covering vehicle conversions, refuelling facilities and health and safety aspects of alternative fuel supply, distribution and end-use.

4.2.1 Mandates

Though not popular on their own without adequate incentives, a variety of mandates can be legislated and implemented to help promote alternative fuels. These can include:

- Purchase mandates for private vehicle fleets to buy AFVs over specified periods,
- Mandates for cities with air pollution problems to ban polluting vehicles in congested downtown areas during certain hours of the day,
- Mandates for municipalities to introduce a percentage of alternative fuel vehicles over a specified period.

Mandates have been employed for the introduction of alternative transport fuels in almost all cases. Specifically, the introduction of ethanol as an alternative transport fuel in Brazil, the conversion of diesel buses and three-wheelers to natural gas (CNG) fuelling in New Delhi and in other Indian cities and the development of electric and flexible fuel vehicles (FFVs) in the United States have all been mandated by governments.

While such mandates can lead to fuel switching and result in short-term benefits, they should be used with caution as they can greatly inhibit technological innovation in the medium and long-term by misdirecting investment to non-viable and uneconomic technologies.

Mandates are best applied in conjunction with incentives, as this helps ensure compliance, and they must both be enforceable and enforced. In general, a transition approach, such as a gradual increase in the percentage of vehicle procurements over time, is most likely to be successful.

4.2.2 Development of Regulations, Standards and Codes of Practice

Standards and codes of practice have already been developed for the use of many alternative transport fuels in most APEC economies, but they require unification and universal adoption throughout APEC. Regulations are required to ensure the application of these standards for the safe and efficient use of alternative fuel vehicles. Policing and enforcement of regulations is essential for successful introduction and development of an alternative fuels market.

4.3 Other Measures

There are several other measures that can be adopted by governments to promote the introduction of alternative transport fuels. These include:

- Funding research, development and demonstration,
- Increasing public awareness,
- Encouraging OEM participation,
- Leadership in the uptake of alternative transport fuels.

These measures are generally of quite affordable to governments but do have significant financial and public relations implications for stakeholders. The ways in which they operate are discussed below.

4.3.1 Funding Research, Development and Demonstrations

Many suppliers of equipment required for the introduction of alternative transport fuels are small under-funded businesses that need assistance - either through direct funding, or from national research organizations - for product development and market introduction.

Governments can support the research, development, demonstration and deployment of alternative fuel technology either through voluntary agreements with OEMs and fuel providers or through direct funding of such activities. Voluntary agreements or collaborative partnerships with industry are usually seen as an alternative to stringent, mandatory regulations and punitive fiscal measures.

4.3.2 Public Education

Information dissemination and education can form a key element of government incentive programmes for alternative transport fuels. They usually take the form of regular communications, such as TV and radio advertising, Web sites or newsletters to inform the public of market and technology developments and to indicate how to apply for subsidies, if available.

The aim is to advance public understanding and awareness of the benefits of switching away from conventional fuels and of the various incentives available to them. In some cases, there is a need to reassure both consumers and the general public about the safety of a particular fuel or fuel use. This has happened in several countries in the case of autogas, which has, at times, been the victim of some mischievous publicity.

4.3.3 Leadership by Example

Governments can provide leadership by encouraging consumers to consider alternative fuel options and by converting their own vehicles or purchasing new AFVs.

The value of changing to new and cleaner fuels can be promoted and public awareness raised. One example is the establishment of "blue corridors." These are heavy transport routes along which facilities are located for the refuelling of alternative fuel buses and heavy trucks.

4.3.4 Transport Control Measures

These involve programs to modify driving behaviour and traffic patterns to facilitate exhaust emission reduction in densely populated urban areas. They are normally implemented by national or municipal authorities and target alternative fuel vehicles.

Table 4.2: Examples of Autogas Incentive Policies

Economy	Fuel tax exemption or large rebate	Vehicle tax exemption or rebate	Grants/tax credits for conversions or OEM purchases	Autogas fleet vehicle purchase mandates
Algeria	Yes			
Australia	Yes	Yes	Yes	Yes
Belgium	Yes			
Bulgaria	Yes			
Canada	Yes			Yes
China	Yes			Yes
Czech Republic	Yes			
France	Yes		Yes	Yes
Italy	Yes		Yes	Yes
Japan	Yes		Yes	
Korea			Yes	
Lithuania	Yes			
Mexico	Yes			Yes
Netherlands	Yes	Yes		
Poland	Yes			
Russia	Yes			
Thailand				
Turkey	Yes			
United Kingdom	Yes	Yes	Yes	
United States			Yes	Yes

Table 4.3: Examples of Mandates and Targets for Biofuels

Country	Mandate
Australia	E2 in NSW to E10 by 2011; E5 in Queensland by 2010 350 million litres of Biofuels by 2010
Argentina	E5 and B5 by 2010
Bolivia	B2.5 by 2007 and B20 by 2015
Brazil	E22 to E25 in use; B2 by 2008 and B5 by 2013
Canada	E5 by 2010 and B2 by 2012; E5 in use in Ontario and E7.5 in Saskatchewan and Manitoba;
Chile	Voluntary E5 and B5
China	E10 in 9 provinces 10 mill tonnes Ethanol by 2010, 30 mill tonnes by 2020 0.3 mill tonnes Biodiesel by 2010, 2 mill tonnes by 2020
Colombia	E10 and B5 in use
Dominican Rep	E15 and B2 by 2015
Germany	E2 and B4.4 in use; B5.75 by 2010
India	E10 in 13 states or territories
Italy	E1 and B1
Malaysia	Mandate for B5 by 2008 suspended
New Zealand	3.4% total biofuels by 2012 (mandate repealed, 2009)
Paraquay	B1 by 2007, B3 by 2008, and B5 by 2009
Peru	B5 and E7.8 by 2010 nationally regionally 2006 (ethanol) and 2008 (biodiesel)
Phillipines	B1 and E5 by 2008; B2 and E10 by 2011
South Africa	E8-E10 and B2-B5 (proposed)
Thailand	E10 by 2007; 3% biodiesel share by 2011
United Kingdom	E2.5 and B2.5 by 2008; E5 and B5 by 2010
United States	130 billion liters/year by 2022 (36 billion gallons) E10 in Iowa, Hawaii, Missouri, Montana; E20 in Minnesota B5 in New Mexico E2 and B2 in Louisiana and Washington State Pennsylvania 3.4 billion liters/year biofuels by 2017
Uruguay	E5 by 2014; B2 from 2008-2011 and B5 by 2012

4.4 Current Incentives

As indicated in the previous sections, there is a wide range of incentives that can be offered to encourage the uptake of alternative transport fuels. Because different economies favour different approaches, there is considerable variation between the policies and measures employed in different economies.

This variation is illustrated in Table 4.2, which summarises a number of autogas incentive policies, and in Table 4.3, which gives examples of current biofuel mandates. Measures that are in place to promote renewable energy generally are listed for a number of economies in Appendix B1.

4.4.1 Australia

Alternative transport fuels (including CNG, autogas, ethanol and biodiesel) currently benefit from a complete exemption from excise duties. The Commonwealth Government also offers rebates for the costs of diesel, autogas and other alternative fuels for some categories of commercial users under the Energy Grants Credit Scheme.

In addition, the Commonwealth Government offers grants covering up to 50% of the cost of conversion or the incremental purchase cost of buses and other heavy-duty commercial vehicles (weighing more than 3.5 tonnes) to run on CNG or autogas. In all cases, a minimum reduction of 5% in GHG emissions must be demonstrated and the vehicle must continue to meet current emission limits for noxious gases. These grants are to be phased out over the period July 2011 to 2015.

Several states have also adopted policies to promote autogas. These include the following:

- Western Australia offers grants of A$500 for private autogas conversions or OEM vehicle purchases,
- The Government of Victoria mandates that a proportion of new high-usage government-fleet passenger six-cylinder vehicles must be able to run on autogas,
- The New South Wales Government has adopted a policy of increasing the share of autogas vehicles in its public fleet, based on CO_2 emission performance. In February 2004, the NSW police force began a programme to replace up to half of its 1,600 passenger vehicles with OEM autogas vehicles,
- The Government of the Australian Capital Territory (ACT) provides a rebate of 20% on the annual vehicle-registration fee for private autogas vehicles.

4.4.2 Canada

The Alternative Fuels Act 1995 requires that a proportion of vehicles purchased by the federal government be capable of operating on one of a range of alternative fuels, including ethanol, methanol, autogas, natural gas, hydrogen, or electricity, where it is cost-effective and operationally feasible. For the purpose of acquiring motor vehicles, this list has now been expanded in the Alternative Fuels Regulations to include biodiesel and blended fuels for which the alternative fuel makes up at least 50% of the blend. Flexible fuel and bi-fuel vehicles are also considered to be AFVs for the purposes of acquiring motor vehicles.

Table 4.4: Federal and State Ethanol Fuel Incentives in Canada

Government	Measures and Incentives
Federal	Gasoline Excise tax exemption, 10 c/litre * US ethanol imports eligible
	Ethanol Expansion * Contingent loan guarantees (C$102 m) * Public awareness (C$2.2 m) * Subsidies for production facilities (C$73 m)
Alberta	C$.25 per gallon tax exemption for 5 years after start-up of an ethanol production plant
	C$209 million over 4 years to renewable fuels *No restriction on ethanol source
Manitoba	C$.07 per/litre tax exemption plus $0.08/litre subsidy
	C$0.25/litre tax credit for fuels with >10% ethanol * fuel must be produced and consumed in Manitoba
	C$0.115/litre tax exemption for biodiesel.
Ontario	C$.09/litre tax exemption to 2012 *5% ethanol in gasoline from January 2007 *Replaced with incentives of C$ million over 12 years
	Use of ethanol blends in government vehicle fleet
Quebec	10c/litre ethanol tax exemption to 2012 *Goal of 5% ethanol in gasoline by 2012 w cellulosic tech.
	Reimbursement of fuel taxes paid on biodiesel
	Income tax credit for ethanol production & sale in Quebec
Saskatchewan	C$0.10/litre tax exemption for 5 years C$0.15/litre tax credit for fuel distributor
	Fuel must be produced and consumed in Saskatchewan * 2.5% ethanol by July 2004, 7.5% by April 2005 *30% ethanol from small plants (<15 m litres)

The Canadian government also makes incentives available for natural gas OEM vehicles and conversions, but not for autogas vehicles. The federal government increasingly favours ethanol through government grants for building refuelling stations, of which there are now more than 1,100. This preference is reflected by each of the Canadian provincial governments, as illustrated by the data in Table 4.4.

Autogas has a significant tax advantage over gasoline and diesel. However, because fuel taxes are relatively low in Canada, differences in prices at the pump are not very large.

In Ontario, the provincial sales tax is refundable up to a limit of C$750 on autogas vehicles and C$1,000 on vehicles powered by alternative fuels other than propane. In addition, the fuel-conservation tax paid on new passenger cars or sport utility vehicles (bought or leased) may be refunded if the vehicles operate, or are converted to operate, exclusively on an alternative fuel. A refund of this tax is not available if a vehicle can operate as a dual-fuel vehicle.

4.4.3 China

The Chinese government promotes the use of alternative transport fuels through fuel-tax incentives and mandated public-transport conversion programmes. There is no excise (consumption) tax on alternative transport fuels and the universal value added tax (VAT) is levied at a lower rate. The government also controls wholesale and retail prices, though there is some flexibility for retailers to adjust prices. Nine provinces mandate an E10 blend with gasoline. The central government does not provide any grants or tax credits for AFV purchases or conversions.

In 1998, the government launched a clean-air scheme to deal with worsening urban pollution problems. As part of this scheme, a program to promote alternative fuels in 14 major cities was mandated. A large proportion of buses in Beijing and some other big cities now run on natural gas and autogas. Currently, there are 104,000 NGV buses in China and more are being converted

Several cities have also mandated the conversion of public taxis to alternative fuels. Almost all of the taxis in Shanghai, for example, have been converted to autogas.

4.4.4 Hong Kong China

In 1997, the government of Hong Kong established an environmental mandate to replace the territory's diesel-powered taxicab fleet with liquefied petroleum gas (autogas) powered vehicles.

To encourage the transition, taxi owners were given cash grants of HK$40,000 to purchase new LPG vehicles and drivers were promised cheap fuel. In exchange for selling at or below capped prices, certain companies received "free" land to develop dedicated autogas filling stations. Other local filling stations sold autogas alongside gasoline and diesel fuel, although at market prices. All stations in the territory are supplied by fuel imported from abroad.

All of the territory's 20,000 taxis now run on autogas and diesel taxis are now banned. More than 30% of public buses are also fuelled with autogas and there is an incentive scheme for minibus operators to switch to autogas.

4.4.5 Japan

Autogas is the most widely used alternative transport fuel in Japan with about 200,000 autogas vehicles currently in operation compared to some 36,000 NGVs. The Japanese government has for many years maintained low excise duties on autogas and natural gas relative to diesel and gasoline. The duty on autogas is less than a third the level of that on diesel and less than a fifth of gasoline.

The government also provides grants covering either the difference in purchase price between a diesel vehicle and an autogas OEM vehicle or the cost of converting a diesel vehicle to run on autogas. Since April 2003, the grant has been set at 50% of the incremental cost and is capped at 200,000 yen (US$1,900) for a light-duty van, small truck or station wagon and 250,000 yen (US$2,350) for a normal truck or bus. A lower local sales tax rate (1.1% compared to the usual rate of 3%) is also applied to OEM autogas vehicle purchases when accompanied by the scrapping of a diesel vehicle.

The government has also established a program to promote autogas distribution through grants covering 50% of the cost of both building and running autogas refuelling stations. The construction and running cost subsidies are capped at 30,000,000 yen per station (US$280,000) and 1,986,000 yen per station per year (US$18,700), respectively. In December 2004, the government approved a 125 million yen (US$1.2 million) R&D study of autogas fuel quality and a 250 million yen (US$2.4 million) project to develop non-sulphur autogas odorant.

Stringent regulations governing noxious emissions in designated urban areas restrict the use of diesel vehicles, thereby favouring autogas. In addition to the lower fuel cost, this is why most operators of high-mileage commercial LDVs generally opt for autogas over diesel.

Japan has permitted the use of ethanol as an E3 blend and has a voluntary target for consumption of 500 million litres of ethanol by 2010.

4.4.6 Korea

Recently, CNG vehicles, LNG vehicles, and HEVs that run on gasoline and electricity, or natural gas and electricity have been introduced in Korea in order to save energy and mitigate pollution in urban areas. Interestingly, the Korean government provides different incentives to promote each alternative transport fuel rather than legislating for alternative transport fuels generally as occurs in many other economies.

Korea was one of the first economies to promote the use of autogas as an alternative transport fuel and has rapidly become the largest autogas consumer in the world with approximately 1.75 million vehicles and 1,250 refuelling stations. Autogas is taxed less than gasoline and diesel but tax differentials have narrowed significantly since 2000 with the result that autogas growth has slowed. Both commercial and non-commercial users also pay value added tax (VAT) of 10% – the same rate as for the other fuels. Pre-tax fuel prices include a 5% import duty on autogas and an 8% duty on gasoline and diesel. An additional import surcharge is currently applied to gasoline and diesel but not autogas.

The Korean government does not make available any grants or tax credits for conversions of light-duty gasoline vehicles to run on autogas or for OEM purchases. However, the Environment Ministry has recently funded a program to convert about 2,000 public diesel vehicles in Seoul, Incheon and Gyeonggi-do to run on autogas.

CNG is now being given favourable tax treatment over autogas and there are currently 17,123 NGVs and 121 refuelling stations in operation. There are many buses operating on CNG. The rapid growth of the Korean NGV industry in Korea is due to the following strong incentives offered by the government.

- VAT, acquisition tax, and customs duty reductions are provided for purchasing NGVs, which are also exempted from a charge for environmental improvement that applies to diesel motor vehicles. Corporate tax cuts and lower industrial electricity fees also apply for natural gas stations. Environmental damage charges applicable to gas stations located in limited development districts can be reduced by 10-20%,

- The price differential between natural gas and diesel vehicles is covered by a grant. In the beginning, only inner city buses were eligible for the grant. However, it is now available for garbage trucks, airport limousines, intercity buses, and school buses. Prime rate loans are also available for the construction of natural gas stations,

- The government partly supports the fuel and operating costs for natural gas buses and gas stations.

The introduction of HEVs is now being strongly promoted by the Korean government. Currently, HEVs enjoy lower highway tolls than conventional fuel vehicles and a more comprehensive incentive package to promote their introduction is soon to be announced.

4.4.7 Mexico

Autogas is the leading alternative transport fuel in Mexico, which ranks fifth in consumption of LPG as a motor fuel worldwide. There is also a small emerging NGV market but biofuels and HEVs are only at a very early stage of introduction.

There are no excise duties on autogas. However, the government has raised autogas prices through direct price controls and the pre-tax price of autogas is significantly higher than that of gasoline or diesel. This is in contrast to most countries where autogas is cheaper.

There are no subsidies for vehicle owners to convert to autogas or CNG or to purchase OEM vehicles. However, most NGVs and autogas vehicles are exempt from anti-pollution driving restrictions in Mexico City and the Mexican Postal Service has announced a major program to convert many of its vehicles to CNG fuelling.

A Biofuels Promotion and Development Law was approved by the Mexican Congress but vetoed by the president on the grounds that it would have put too much emphasis on corn and sugarcane production. A new bill is in the development stage.

Mexico City officials, with help from a $200 million environmental grant from the Clinton Foundation, have developed a pilot program to stimulate HEV purchases by city employees by waiving down payments and interest charges. There are no plans to extend the program to the general population. Mexico City does, however, offer HEV owners a combination of limited tax breaks and relief from the city's rigorous emissions verification program.

4.4.8 Russia

The primary alternative transport fuel in Russia is autogas (550,000 vehicles) followed by CNG (95,000 NGVs). Biofuels and HEVs are not yet in the market.

The main government incentive for autogas in Russia is the exemption from excise duty. This, in conjunction with a relatively low pre-tax LPG price, provides a large price differential against gasoline and, to a lesser extent, diesel at the pump. There are no other fiscal or regulatory incentives for either autogas or NGVs.

Currently, there is no federal legislation nor incentives to encourage the production and consumption of fuel ethanol in Russia. Legislation that lifts the excise taxes and eases regulation on motor fuel containing less than 10% ethyl alcohol has been drafted but not yet considered by the government. This legislation is intended to make bioethanol more economically attractive for alcohol-producing plants.

4.4.9 Thailand

Thailand has been extremely active in the introduction of alternative transport fuels. The primary alternative transport fuel is autogas (1.2 million vehicles), followed by CNG (117,727 NGVs) and biofuels (both ethanol and biodiesel). Production of HEVs in Thailand is just commencing.

The Thai government has been aggressive in promoting the use of alternative transport fuels by establishing strong incentives for many consumers to switch from conventional gasoline and diesel. These include lower fuel taxes, fuel subsidies, fuel price control, reduced new vehicle sales taxes and mandated alternative transport fuel introduction and government fleet conversion targets. Interestingly, the reduction of new vehicle sales taxes makes all AFVs cheaper than their conventional counterparts.

The fuel taxation system in Thailand is quite complex. Taxes include an excise tax (ETAX), a municipal tax (MTAX), an Oil Fund Tax and an Energy Conservation Fund tax. Additionally there is a value added tax (VAT).

Autogas has an excise duty that is roughly half that of diesel and a third of gasoline. Duties have not changed since the 1990s and the government controls the pump price of autogas through a fixed distribution margin. As a result, the pre-tax price is significantly lower than that of the other fuels. In absolute terms, the fuel price differential has widened in recent years as gasoline and diesel prices have increased more rapidly than autogas prices. This has provided such a strong incentive for consumers to switch to autogas that Thailand now needs to import LPG. Autogas pump prices currently enjoy a 60% subsidy and are the same for commercial and private consumers as commercial users cannot recover sales taxes (VAT).

There are no subsidies for the conversion of gasoline vehicles to autogas. Moreover, the government has adopted a policy of promoting the use of natural gas for vehicles (NGV), ethanol blends and biodiesel to utilize indigenous gas resources and reduce LPG imports. This has been extremely successful as the number of NGVs and CNG refuelling stations has increased from 34,000 and 44, respectively, in June 2007 to 117,727 and 253 today.

Meanwhile, autogas vehicle numbers have burgeoned from 40,000 in 2003 to more than 1.2 million today even though autogas is not targeted in the government's alternative transport fuel consumption targets for 2011, which are shown in Table 4.5.

Table 4.5: Alternative Fuels Consumption Targets in Thailand (2011)

Energy Type	Fuels		% of total energy
	Million litres/day	**ktoe**	
2011 target	7	6,426	13.5
Renewable Energy	7	2,078	8.3
Ethanol	3	820	1.0
Biodiesel	4	1,258	1.5
NGV (mmscfd)	508	4,348	5.2

Policymakers in Thailand have taken measures to increase investments in the production and use of ethanol, including a Board of Investment (BOI) privilege for a fuel ethanol plant, a waiver on the excise tax for the ethanol blended in gasohol, a low rate of oil fund levy, and expansion of cassava production (Table 4.6). Also, the government has set gasohol prices around 2.0 - 2.5 baht/litre cheaper than regular and premium gasoline. It is a requirement that all government fleets be fuelled with ethanol blends.

Table 4.6: Federal and Provincial Ethanol Fuel Incentives in Thailand

Incentive Type	Measures
Tax Incentives	Tax holidays up to 8 years.
	50% reduction in corporate income tax.
	Exemption or reduction of import duties on machinery.
	Exemption of import duties on raw materials.
Non-Tax Incentives	Land ownership rights for foreign investors.
	Permission to bring in foreign experts and technicians.
	Work permit and visa facilitation.
Investment promotion zone-based Incentives	Corporate income tax holiday up to 8 years by zone
	Machinery and raw material import duty reductions or exemptions by zone,
	Additional incentives for one provincial Zone includes double taxable income deduction for transportation, electricity and water costs up to 10 years.
	Deductions for Infrastructure and construction costs.

In response to a proposal by the Excise Department, Thailand's Cabinet approved an excise tax reduction for cars using gasoline containing at least 20% fuel ethanol, effective January 1, 2008. The excise tax cut will lower the price of cars such that a vehicle with a cylinder capacity of no more than 2,000 cm^3 and an engine performance of no more than 220 hp will be taxed at 25%, down from a previous 30%. Cars with a cylinder capacity of no more than 2,500 cm^3 and no more than 220 hp will be charged at 30%, down from 35%. Finally, cars with a cylinder capacity between 2,500 and 3,000 cm^3 and no more than 220 hp will be taxed at 35%, down from a previous 40%. The rates apply to passenger cars and vans with fewer than ten seats.

The Excise Department estimates that about 30,000 new vehicles powered by E20 or higher will be in the market in 2008.

The Thai government announced its Strategic Plan on Biodiesel Promotion and Development in January 2005. The plan targets replacing 10% of diesel consumption in 2012 by increasing palm oil cultivation, and promoting community-based and commercial biodiesel production. A B2 mandate, introduced in February 2008, would require the production of approximately 420,000 tonnes of biodiesel per year. The government is also making available 3 billion baht in soft loans to farmers growing palm crops. It also supports R&D of other crops such as jatropha. A B5 mandate is planned to be introduced in 2011 and a B10 mandate in 2012.

The Thai government does not impose taxes on biodiesel and subsidizes biofuel via its Oil Fund Tax, which is funded from the surcharges on the domestic retail prices of diesel and gasoline.

4.4.10 USA

The USA is the only APEC economy that has enacted legislation that encompasses all of the alternative transport fuels. The Energy Policy Acts of 1992 and 2005 have been the main thrust of federal efforts to promote alternative fuels in recent years. They specify alternative fuels as including:

- Methanol, ethanol, and other alcohols,
- Blends of 85% or more of alcohol with gasoline,
- Natural gas and liquid fuels domestically produced from natural gas,
- LPG (including propane),
- Coal-derived liquid fuels,
- Hydrogen,
- Electricity,
- Biodiesel,
- Fuels (other than alcohol) derived from biological materials,
- P-series fuels (These are a blend of 35 percent natural gas liquids (pentanes plus) and 45 percent ethanol, with the remaining 25 percent a biomass-derived co-solvent methyltetrahydrofuran (MeTHF). The biomass portion is utilized from grass and paper waste in addition to agricultural waste).

Although the aim is to promote all of these fuels, those that have achieved commercial reality are: NGVs (100,000 vehicles), autogas (190,000 vehicles), ethanol (7,289,908 vehicles including blends and FFVs), biodiesel (25,000 fleet vehicles), EVs (120,000 vehicles) and HEVs (1,006,301).

4.4.10.1 Federal Clean-Fuel Vehicle Incentives and Mandates

The EPAct has established a goal of replacing 10% of oil-based motor fuels in the USA by the year 2000 and 30% by the year 2010. It provides two principal instruments to promote the use of autogas vehicles:

- Tax credits and deductions for the purchase of AFVs or conversion of existing conventional vehicles to run on alternative fuels and for the development of supply infrastructure,
- Mandates on federal, state, and private “alternative fuel provider” fleets to purchase AFVs.

The ways in which the tax incentives work are presented briefly below.

Alternative Motor Vehicle Credit

This legislation provides a tax credit equal to 50% of the incremental cost of the vehicle, plus an additional 30% of the incremental cost for vehicles with near-zero emissions. The figures are based on vehicle weight as follows:

- US$5,000 for 8,500 gross vehicle weight rating (GVWR) or lighter,
- $10,000 for 8,501 to 14,000 GVWR,
- $25,000 for 14,001 to 26,000 GVWR,
- $40,000 for 26,001 GVWR and heavier.

A larger incentive of up to $50,000 is currently available for buses and trucks.

Hybrid Motor Vehicle Credit

This tax credit is for light-duty hybrid vehicles (less than 8,501 GVWR) based upon their improved fuel economy and lifetime fuel savings potential. The credit has two parts: the fuel economy portion, which ranges from $400 to $2,400, and the conservation credit, which ranges from $250 to $1,000.

Fuel Cell Motor Vehicle Credit

For the purchaser of a light-duty FCV, there is a base tax credit of $8,000 valid until December 31, 2009, after which it decreases to $4,000. Qualifying vehicles must meet Tier 2 Bin 5 emission levels.

Additional base tax credits are available for medium- and heavy-duty FCVs. The amounts are based on a sliding scale by vehicle weight. This credit is available until December 31, 2014.

Electric Vehicle Tax Credit

This credit was reduced by 75% in 2006 and expired in 2007. The credit provided 10% of the cost of the vehicle, up to $4,000, provided that it was powered primarily by an electric motor drawing current from batteries or other portable sources of electricity. Business or personal vehicles qualified.

Additionally, a tax deduction of up to $100,000 per location is available for qualified electric vehicle recharging stations used in a trade or business.

Clean Diesel Tax Credit

This tax credit is similar to the Hybrid Motor Vehicle Credit (see above), in that it offers an income tax credit for the purchase of models that qualify for the Advanced Lean Burn Technology Motor Vehicle Tax Credit.

Alternative Fuel Infrastructure Tax Credit

This is a credit of up to $30,000 (equal to 30% of the cost of the alternative refuelling property), normally reserved for businesses, but it also applies to buyers of residential refuelling equipment, who can receive a tax credit of $1,000. The credit is effective on equipment put into service after December 31, 2005, and expires December 31, 2009 (the hydrogen credit portion is good until 2014).

Mandates

The EPAct requires all federal fleets consisting of at least 20 or more LDVs operating in a "metropolitan statistical area" to purchase a specific minimum percentage of AFVs. In addition, the State and Alternative Fuel Provider Fleets Program requires all state and alternative fuel provider fleets to purchase a minimum number of such vehicles as a proportion of their annual LDV acquisitions. Fleets earn credits for each vehicle purchased and those credits earned in excess of their requirements can be banked or traded with other fleets. This gives fleets flexibility in meeting their requirements. The mandate does not apply to private and local fleets on the grounds that it would have little impact on fuel use.

4.4.10.2 Fuel-Tax Differentials

There are no alternative transport fuel subsidies based on fuel tax in the USA. This has led to the anomalous situation where autogas for non-commercial users is more expensive on a per litre basis than gasoline.

4.4.10.3 State Programs

Most US states make additional fiscal incentives available to support particular alternative fuels, as summarized in Appendices B2, B3 and B4. Current programs include the following:

- The Colorado Department of Revenue offers a tax credit for the purchase of new AFVs and for the conversion of conventional vehicles to alternative fuels,
- In Connecticut, the incremental cost of purchasing a new vehicle exclusively fuelled by CNG, LNG, autogas or electricity is eligible for a 10% corporate-tax credit,
- Georgia offers a tax credit towards the purchase, lease, or conversion of a vehicle that operates solely on an alternative fuel and is certified as a low emissions vehicle,
- The Louisiana Department of Natural Resources offers a state income-tax credit worth 20% of the cost of converting a vehicle to operate on an alternative fuel, 20% of the incremental cost of purchasing an OEM AFV and 20% of the cost of constructing an alternative fuel refuelling station,
- The Utah Clean Fuels Grant and Loan Program provides grants worth up to 50% of the cost of converting a vehicle to run on a clean fuel ($2,500 maximum) and/or up to 50% of the incremental cost of purchasing an OEM vehicle ($3,000 maximum).

5. Case Studies

The following case studies have been chosen to illustrate how the impediments and barriers to development of alternative transport fuels industries have been addressed in selected APEC and other economies. The objective is to identify and evaluate:

- The drivers for each alternative transport fuels program throughout the APEC economies,
- The impediments to the introduction of alternative transport fuels and how they have been successfully overcome,
- The institutional structures and regulatory regimes required for successful introduction of alternative transport fuels,
- The commercial models that have been developed.

The case studies presented are:

- NGVs in New Zealand, Malaysia and India,
- Autogas in Australia, Japan, Korea and Thailand,
- Ethanol in Brazil and the USA,
- Biodiesel in Thailand,
- Synthetic gasoline in New Zealand,
- EVs in China,
- HEVs in the USA.

5.1 Natural Gas Vehicles in New Zealand

The following case study of NGV introduction in New Zealand is presented in considerable depth. This is because it is unique in representing a “boom to bust” alternative fuels industry experience from which much can be learned. Also, the authors of this report were intimately involved in the New Zealand NGV industry right throughout its short history and are therefore well placed to provide critical commentary and analysis.

Background

New Zealand led the world in CNG development in the mid 1980s. At that time, no other country had such a high proportion (10%) of its gasoline vehicles converted to CNG. From 1979 to 1985, the numbers of NGVs approximately doubled every year – a 100%

annual growth rate (Figure 5.1). From 1982 to 1986, the average annual rate of growth of gas sold as CNG was 50%. By 1986, there were 530 refuelling stations and CNG comprised 10% of fuel supplies used by some 135,000 spark ignition powered vehicles in the North Island, where natural gas is available.

In early 1986, however, the CNG industry stopped growing almost overnight and within ten years was effectively extinct. Today, there are only about 250 vehicles and 14 refuelling stations left and most of these are in fleet operations.

Drivers

The introduction of CNG as an alternative vehicle fuel in New Zealand was determined partly by the oil shocks of the late 1970s and partly by the availability of surplus natural gas that the government had contracted under a take-or-pay agreement to develop the Maui gas field. In the late 1970s, it was apparent that this gas would not be required for electricity generation as originally forecast and an amount of 9PJ was notionally earmarked for use as CNG.

By this time, New Zealand had experienced shortages in conventional fuels, which resulted in car-less days and rapidly increasing fuel prices. Being remote from the sources of crude oil supply, New Zealand felt the need to improve its energy security position and move towards national self reliance. This fitted well with the government's goals of improving the economy and increasing employment and these factors taken together provided strong drivers for the uptake of CNG. Air pollution and emissions were not an issue of concern at that time.

In overview, the CNG program was implemented because the government of the day saw it as an aid to the solution of New Zealand's economic problems – balance of payments and employment. The New Zealand economy at that time was highly regulated with government involvement in most economic activities.

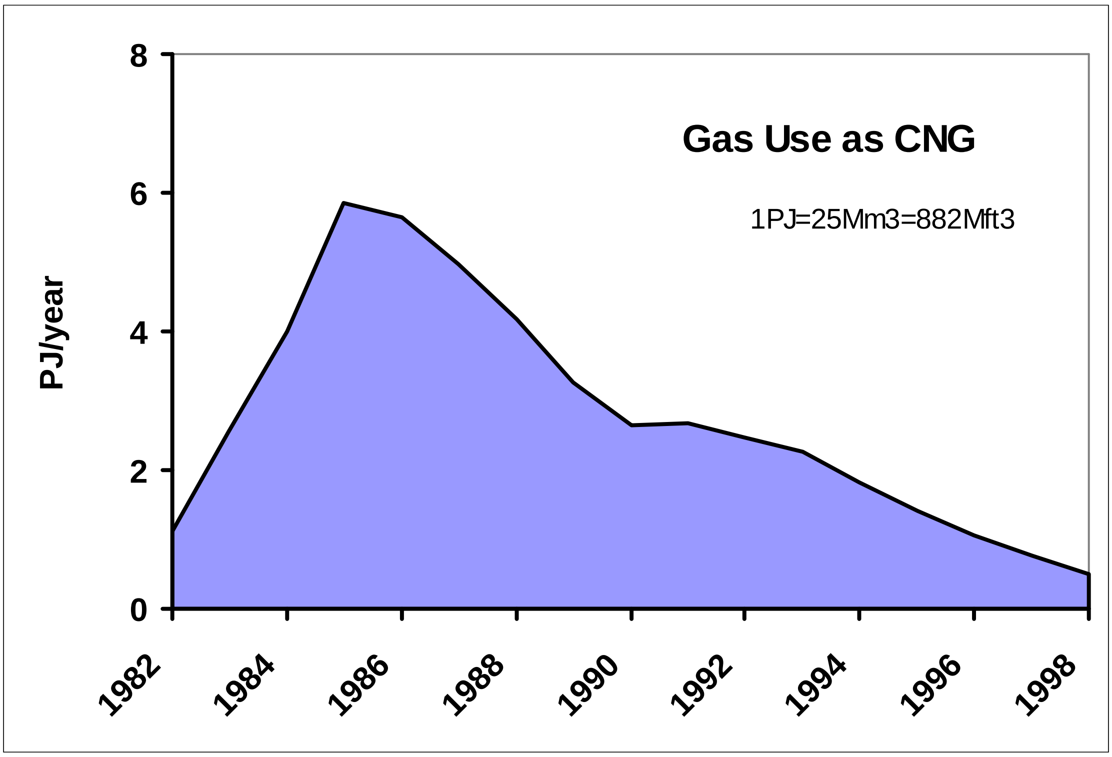

Figure 5.1: Natural Gas Consumption by NGVs in New Zealand

Responsible Agency/Champion

The New Zealand government was ultimately the responsible party for introducing CNG in New Zealand. Initially, it operated through the New Zealand Energy Research and Development Committee (NZERDC), which had representation from both government and private sector interests, and which was funded to commission energy research and studies that addressed national energy needs. It was the NZERDC that drew up the initial CNG implementation plan.

A second body, the Liquid Fuels Trust Board (LFTB), was set up in 1979 under its own Act of Parliament and charged with the task of making New Zealand independent from imported transport fuels. Together, these two agencies initiated the government role in promoting the program. Later the Ministry of Energy and a number of other government ministries and agencies participated actively under the coordination of the CNG Coordinating Committee (CCC), set up to coordinate the needed activities of government agencies and to oversee the program generally. The agencies involved and their functions are listed in Table 5.1. Three ministers of energy presided over the CNG implementation program until 1986 and all proved to be strong champions.

Table 5.1: Responsible Agencies and Functions for NGV Introduction in New Zealand

Agency	Function
Ministry of Energy	Became Lead Agency in 1981
Ministry of Transport	Regulation of vehicle equipment and installations
Department of Labour	Regulation of vehicles
Department of Education	Training of vehicle installers
Ministry of Works Post Office	Conversion of large fleets of Government vehicles
Standards Association of New Zealand	Standards for vehicle conversion and refuelling stations
Development Finance Corporation	Loans for refuelling stations and larger fleets
Natural Gas Corporation	Bulk gas to existing gas franchise areas and retailing of gas outside franchise areas
NZERDC and LFTB	Funding and management of reserach on various topics related to CNG
CNG Coordination Committee	Program coordination and resolution of issues

Impediments Encountered

Initially, there was considerable resistance to the introduction of CNG from both government and private sectors. The oil companies and automobile manufacturers, for example, were not keen to accommodate the new fuel. Also, many technical problems were encountered in vehicle conversion using primarily Italian equipment that was not always suited to purpose. The NZERDC and LFTB were pivotal in identifying and solving the technical problems through specifically targeted R&D.

In addition, there were a number of legal and regulatory problems, many relating to gas delivery and storage pressures. All of these problems led to bad publicity, which created a barrier to the uptake of CNG by the motoring public.

Chronology and Solutions

In April 1979, the New Zealand Government adopted a target of 150,000 vehicles to be operating on CNG by the end of 1985. It then commenced to establish the infrastructure to support the implementation (e.g. training equipment installers, establishing standards for vehicle conversion and refuelling stations, publicity etc.). The target was subsequently modified to 200,000 vehicles by 1990. However, in 1984, the target and incentives were abandoned by the new Labour Government as part of its changed economic policy.

In April 1979, an incentive package was established to include grants of NZ$200 towards vehicle conversion and 25% of the capital cost of establishing a CNG refuelling station. In addition, the retail price of CNG was held at 50% of the gasoline price on a litre equivalent basis.

Throughout the course of the CNG program, the NZERDC conducted a series of market surveys to track industry growth and performance. Based on the outcomes of these, several changes were made to the financial incentives available. These included the introduction of accelerated depreciation on equipment in 1980, interest free loans for vehicle conversion and an industry based initiative which provided NZ$300 of free CNG for each new conversion.

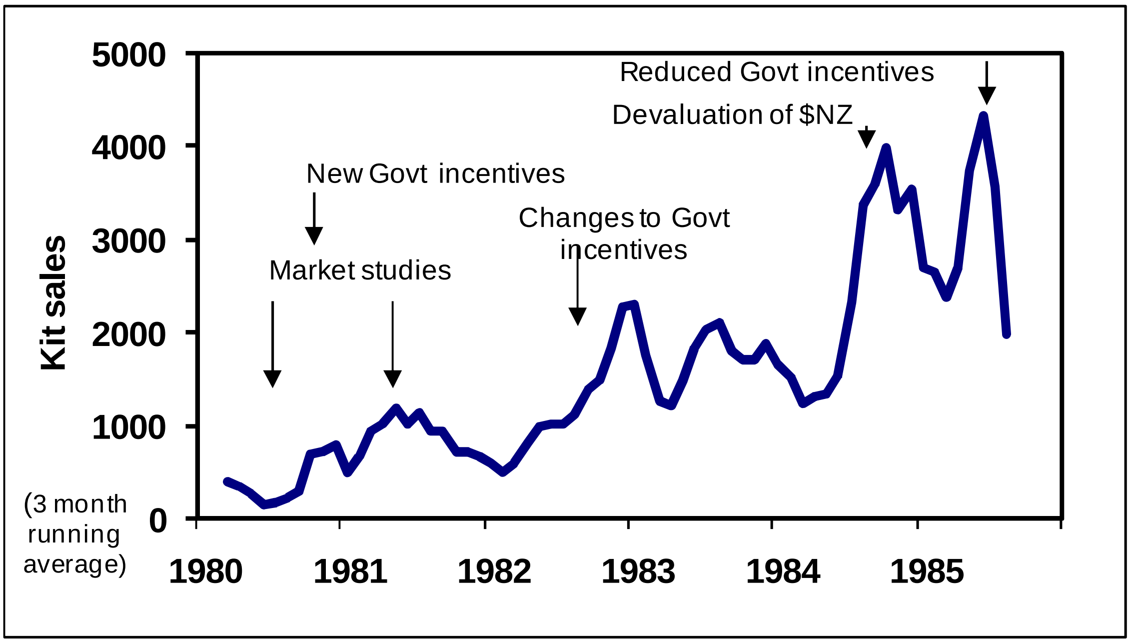

Figure 5.2: Annual CNG Conversion Kit Sales in New Zealand

These actions and initiatives clearly had an effect on CNG uptake, as illustrated in Figure 5.2. In addition, the establishment of an industry association and the development of institutional infrastructure were important factors in the development of New Zealand’s NGV industry.

Outcomes

By 1985, the NGV industry was well established with approximately 135,000 vehicles and 530 refuelling stations. The industry was, however, still strongly supported by government financial incentives. In 1985, a new government initiated massive economic reforms with widespread deregulation. The removal of incentives for the NGV industry was part of this deregulation and resulted in an immediate loss of public confidence in the still immature NGV industry. Vehicle conversions stopped almost overnight and the public perception was that if the government no longer supported the NGV industry then it had no future. The problem was compounded by the dramatic fall in crude oil prices in January 1986. Although the pump price of CNG was still only half that of gasoline, the absolute financial advantage was significantly reduced.

Lessons Learned

The most outstanding features of New Zealand's NGV experience have been:

- The rapidity with which CNG was established,
- The high growth rate in the period from 1979 to 1985,
- The boldness to engage in hindsight reviews over that period and couple the results of those reviews with changes of policy, incentives, research and institutional development,
- The collaboration between government and industry through the CNG Coordination Committee and other organisations.

A number of lessons can be learned from the New Zealand NGV experience. These can be summarized as follows:

- A new industry needs a champion – preferably in both the government and private sectors,
- The combination of government leadership and willingness of the private sector to accept risk proved to be a sound basis for the introduction of NGVs,
- Financial incentives are necessary for the introduction of NGVs, but these must be managed in response to periodic market studies to address the changing needs of the developing industry. The CNG price differential should be sufficient to maintain an incentive for the initial conversion and continued use of CNG,
- Government and industry must collaborate to establish the necessary institutional infrastructure (standards, regulations, training) for regulation of the NGV industry at an early stage of its development,
- Incentives for the early investment in refuelling stations that are comparable to gasoline stations greatly assist industry development as evidenced by the fact that a shortage of refuelling facilities was not a problem in New Zealand, except at the very early stages of the program,
- Vehicle conversions, OEM conversions and refuelling equipment must be of high technical quality,

- Maintenance of public confidence in an NGV industry is essential and the sudden removal of government support can kill an industry that was otherwise developing well,

- Great care must be exercised in decoupling government involvement in a new industry until it reaches maturity.

5.2: Natural Gas Vehicles in Malaysia

This case study has been chosen because it represents the well ordered development of a new alternative transport fuels industry under the management of a national oil company.

Background

The NGV program in Malaysia began in 1984 at a time when the high price of crude oil had led many economies to investigate alternative transport fuels. There are now about 40,000 NGVs operating in the country, with a total of 101 NGV stations. Presently bi-fuel vehicles (i.e. after-market conversions) dominate the NGV population in Malaysia, which consists mainly of city taxis.

About 300 conversions are recorded every month and the numbers are on the rise. All taxis in the Klang Valley (around Kuala Lumpur), Penang and Johor are targeted to be converted by the end of 2009.

Drivers

The NGV industry in Malaysia is primarily driven by concern for the environment. In addition it provides opportunity to increase and diversify the use of Malaysia's substantial domestic natural gas reserves, thereby increasing energy security.

Responsible Agency/Champion

Throughout its life, the NGV industry in Malaysia has been the responsibility of the national oil company, Petronas. The program was, however, implemented with the support of the government NGV taskforce chaired by the Economic Planning Unit of the Prime Ministers Department and made up of representatives from relevant government departments.

As commercialization proceeded, Petronas established a wholly owned subsidiary, Petronas NGV Sdn Bhd (PNGV) in 1995. The objective was to give more focus to the development and commercialization of NGV in Malaysia. Key strategies of PNGV are:

- Working towards a critical mass,

- Infrastructure development,

- Optimisation of costs,
- R&D.

Impediments Encountered

The limited availability of natural gas pipelines was a significant impediment to the early introduction and growth of the NGV industry and mother-daughter stations have been employed in strategic areas where there are no pipelines. The scarcity of land in some strategic locations within the targeted areas has also adversely affected network development.

In common with most CNG programs, there was an initial perception that NGVs were "unsafe," and early NGV marketing was a big challenge. The resistance was, however, largely due to a sense of comfort with traditional fuels and scepticism about whether NGV was a reliable product as promoted.

Other impediments noted particularly by private users included:

- The cost of vehicle conversion,
- Loss of boot/trunk space with installation of the CNG cylinder,
- Increase of the dead weight of the vehicle,
- Loss of vehicle warranty.

Chronology and Solutions

The NGV program in Malaysia began with a feasibility study, commissioned by Petronas in 1984, to assess the viability of utilizing natural gas in the transportation sector. The study identified several benefits to the country and consumers, including the environmentally friendly characteristics of natural gas and the security of its supply.

A pilot program was conducted between 1986 and 1988 to understand the technology and to lay the framework for a commercial program. This took place at a gas processing plant in Kertih, Trengganu, and involved the construction of one NGV outlet and the conversion of 21 Petronas vehicles to bi-fuel operation. The program showed that the fuelling of vehicles with CNG was viable under Malaysian conditions.

Recognising the potential for this new industry, the government gave approval for Petronas to embark on an initial commercial program. This started in 1991 in the Klang Valley with the objective of identifying and resolving issues and paving the way for wider implementation.

The main supply of gas was from the Peninsular Gas Utilisation (PGU) project, which supplies natural gas to the west coast of Malaysia. Six mother-daughter stations were also established in the Klang Valley to extend the limited gas distribution network since the nearest pipeline was 40 kilometres from the city.

From the outset, city taxis were targeted as the prime candidates for NGV conversion and the Commercial Vehicle Licensing Board passed a regulation requiring that 25% of new taxi fleets (with new permits) and all new taxis (replacing old taxis) be NGVs.

A number of incentives have been offered throughout the course of the NGV program. Initially, taxis were offered a personal or corporate loan for vehicle conversion and the price of CNG was set at half that of gasoline on a litre equivalent basis. Later, in 1995, the government added two more incentives:

- A road tax deduction of 25% for bi-fuel and dual-fuel vehicles and 50% for dedicated NGVs,

- Accelerated capital depreciation for the purchase of dedicated CNG buses and the construction of NGV refuelling stations.

In addition, Petronas has also provided incentives in the form of a rebate for conversion in order to spur the market. The scheme was introduced in 1999 for a period of three years and about 6,000 taxis benefited from it.

In 1998, Petronas undertook a major initiative by jointly manufacturing (with Matra of France) 1,000 Enviro 2000 NGV taxis. This was a national initiative to provide local transportation that is environmentally friendly, efficient, and economical. To date, there are Enviro 2000 taxis that have achieved mileages well in excess of 600,000 km and are still in operation without major problems. The engine and the CNG equipment, including the installed composite cylinder, have proven that they can withstand the hot and humid climate and the traffic conditions of Malaysia. Tests have proven that vehicles driven more than 400,000 km are still able to meet Euro 2 exhaust emission standards.

Enviro 2000 NGV taxis were developed according to ISO standards. The aerodynamic body panel is made of advanced composite material that is light, durable, and strong. There are three type 4 composite NGV cylinders that have been tested according to ISO 11439. The Enviro 2000 taxis have also been jointly promoted in several ASEAN economies including Thailand, Singapore, and the Philippines.

Up until 2005, annual growth in the NGV population (excluding motorcycles) averaged 70%. This has, however, increased greatly during the last few years, as shown in Figure 5.3. There are now over 40,000 NGVs and 101 refuelling stations in Malaysia.

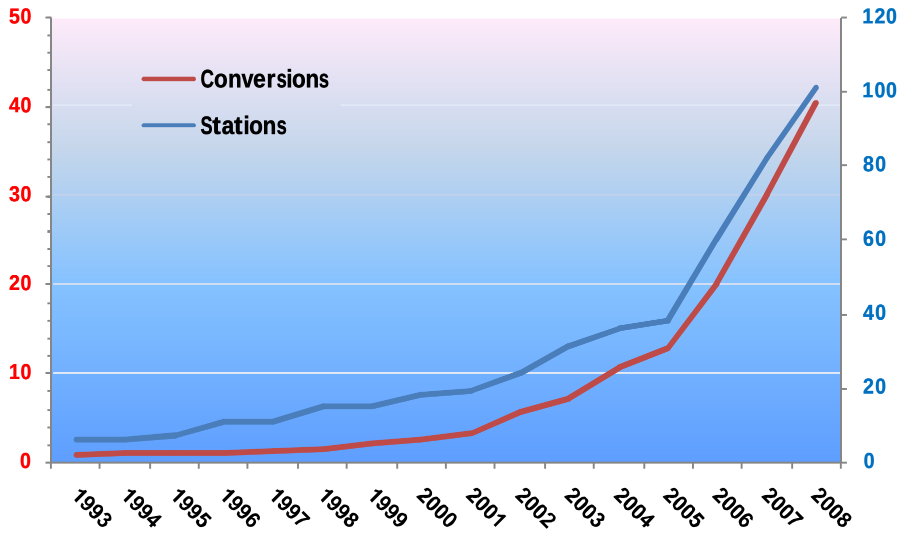

Figure 5.3: NGV Conversions (thousands) and Refuelling Stations in Malaysia

The conversion of diesel vehicles to CNG fuelling is, however, still a challenge as many users of HDVs are still apprehensive due mainly to the high capital cost required for conversion of a diesel engine to natural gas fuelling. In addition the price differential between the CNG and diesel is much less than between CNG and gasoline, as shown in Table 5.2.

Table 5.2: Retail Prices of Automotive Fuels in Malaysia (2008)

Fuel	RM (sen/litre)	US$ (cents/litre)
Gasoline	142	37.3
Diesel	83.1	21.8
CNG	63.5	16.7

Outcomes

NGV industry growth has proceeded as illustrated in Figure 5.3, with about 90% of NGVs being city taxis.

PNGV is also focussing efforts on the heavy-duty market with emphasis on heavy-duty vehicle conversions in the Klang Valley and Johor Bahru. Central to this is a city bus program and interest in the use of CNG in trucking fleets in light of rapidly increasing diesel prices.

A wide range of institutional issues has now been satisfactorily addressed. They included the approval of facilities and equipment and certification of NGV technicians. The standards MS1204 for the construction of NGV stations and MS 1096 for vehicle conversion have been developed and the certification program for NGV installers established.

Future plans are to have 94 NGV stations serving 54,000 vehicles by 2010. To this end PNGV is working to ensure industry sustainability through the following activities:

- Achievement of critical mass by focusing efforts on public vehicles such as taxis, buses and HDV fleets,
- Leveraging off the government's continuous commitment and support of the NGV industry,
- Accelerating the development of the NGV refuelling network. The strategy is to build more stand-alone NGV Stations with more dispensing facilities in order to alleviate congestion issues at existing stations,
- Improvement of NGV technology by undertaking R&D,
- Promoting the development of an ancillary service industry.

Lessons Learned

The following lessons can be learned from the Malaysian NGV experience:

- Appointment of the national oil company as champion for, and organizer of, NGV industry development enables coherent and orderly industry growth,
- Ongoing government support and provision of financial incentives is required for the introduction of NGVs,
- There is a need for early establishment of a comprehensive refuelling network without which NGV industry growth will be inhibited,
- There is a need to develop a critical mass in order to achieve a sustainable NGV industry,
- The development and maintenance of public confidence in an NGV industry is essential,
- The development of purpose-built NGVs (the Environ 2000 Taxis) can significantly assist in promoting both public acceptance and industry growth.

5.3: Natural Gas Vehicles in India

This case study has been chosen because it illustrates how an alternative transport fuel can be mandated to reduce local air pollution and implemented in the absence of a natural gas pipeline network.

Background

In the early 1990s, New Delhi had the dubious distinction of being one of the most polluted cities in the world due to the exhaust emissions from some 21 million vehicles including two and tree wheelers.

In response to this concern, and recognizing the increasing use of CNG to reduce exhaust emissions in other parts of the world, Public Interest Litigation (PIL) had been filed in 1985 in the Supreme Court of India seeking intervention. The Supreme Court responded by directing the Government of India to promote the use of CNG as a transport fuel in New Delhi to control the increasing level of ambient air pollution.

A number of additional cities were also included in the Supreme Court directive at a later date but in some of these (Jodhpur and Jharia) urban air pollution is mainly due to dust rather than vehicular emissions. Meanwhile, the introduction of CNG as a vehicle fuel has also proceeded in Mumbai, Maharashtra, and Gujarat Province, where natural gas pipeline networks are available.

Drivers

The NGV market in India has developed almost exclusively in response to a single driver, *viz*. the need to reduce urban air pollution from automobile exhaust emissions.

Thus, on July 28, 1998, the Supreme Court of India issued an order to the Government of the National Capital Region (NCR), which includes the city of New Delhi, with a time frame for the following actions:

- Replacement of all pre-1990 auto-rickshaws and taxis with new vehicles using clean fuels by March 31, 2000,
- Financial incentives for replacement of all post-1990 autos and taxis with new vehicles using clean fuels by March 31, 2001,
- No buses more than eight years old to operate except on CNG or other clean fuels, after March 31, 2000,
- The entire Delhi Transport Corporation (DTC) and private bus fleet to be converted to dedicated CNG operation by March 31, 2001,
- New interstate bus terminals (ISBT) to be built in the north and southwest of New Delhi by March 31, 2000, to avoid pollution from interstate buses,

- The Gas Authority of India, Ltd. (GAIL) to expand its CNG dispensing capacity to 80 stations by March 31, 2001,
- Two independent fuel testing labs to be established by June 1, 1999,
- Inspection and maintenance (I&M) facilities for commercial vehicles to be set up immediately,
- Comprehensive I&M programs to be started by the Transport Department and the private sector by March 31, 2001.

Responsible Agency/Champion

The ultimate champion of the NGV program in India should probably be seen as the Supreme Court of India, which has also maintained an ongoing oversight of, and interest in, its effectiveness. Responsibility for implementation, however, was assigned to the government gas company GAIL.

Subsequently, in December 1998, a new joint venture company, Indraprastha Gas Limited (IGL) was incorporated to implement the orders of the Supreme Court with regard to the expansion of the CNG program in New Delhi. The IGL joint venture partners are GAIL, Bharat Petroleum Corporation Limited (BPCL), and the Government of the National Capital Territory (NCT of New Delhi).

Impediments Encountered

The following impediments were encountered in implementing the introduction of CNG as an alternative transport fuel:

- Limitations on natural gas allocation leading to delays in management decisions and expenditure commitment,
- Uncertainty about conversions of vehicles and likely CNG demand,
- Lack of indigenous technology,
- The capital intensive nature of the project,
- Infrastructure constraints (e.g. electricity, land availability),
- Delays in obtaining approvals from statutory authorities due to lack of institutional infrastructure,
- Objections from local people about the encroachment of CNG distribution infrastructure,
- Low storage capacity of onboard CNG cylinders requiring frequent refuelling.

Chronology and Solutions

The NGV program in India was initiated with a pilot project conducted by GAIL in conjunction with the Indian Institute of Petroleum (IIT) to establish the feasibility of using CNG as an alternative transport fuel for buses and automobiles in New Delhi, Mumbai, and Baroda.

Refuelling in New Delhi was accomplished by having three mother stations supplied by pipelines and an additional six daughter stations to which CNG was transported, in baskets of 20 cylinders, by truck.

Following the successful conduct of the pilot trial, the Supreme Court in 1998 directed GAIL to expand the CNG infrastructure and to increase the number of CNG stations in New Delhi. It also directed the government of New Delhi to convert the entire city bus fleet, automobiles, and taxis from liquid fuel to CNG. Today, there are approximately 850,000 NGVs operating throughout India and approximately 325 refuelling stations. The majority of these vehicles are auto-rickshaws.

Early growth of the NGV market in New Delhi is illustrated in Figure 5.4 and the corresponding growth in CNG consumption in Figure 5.5.

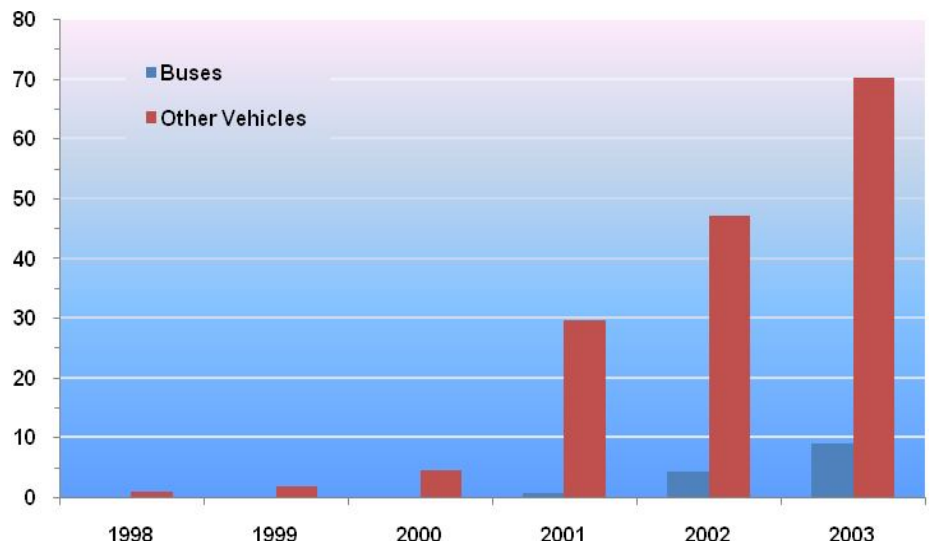

Figure 5.4: Initial Growth of CNG Vehicle Numbers in New Delhi (thousands)

Since the beginning of 2004, however, the NGV industry both in New Delhi and nationwide has roughly doubled in size as shown in Figure 5.6.

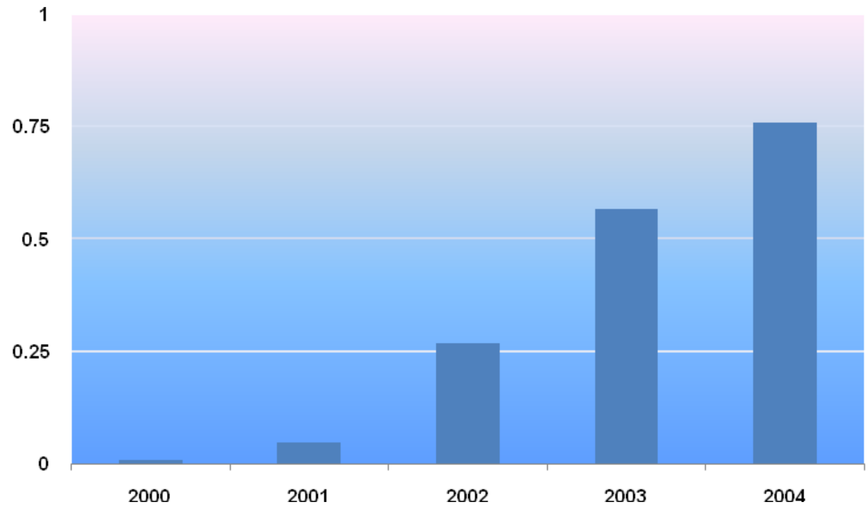

Figure 5.5: Initial Growth of CNG Consumption in New Delhi (million kg/day)

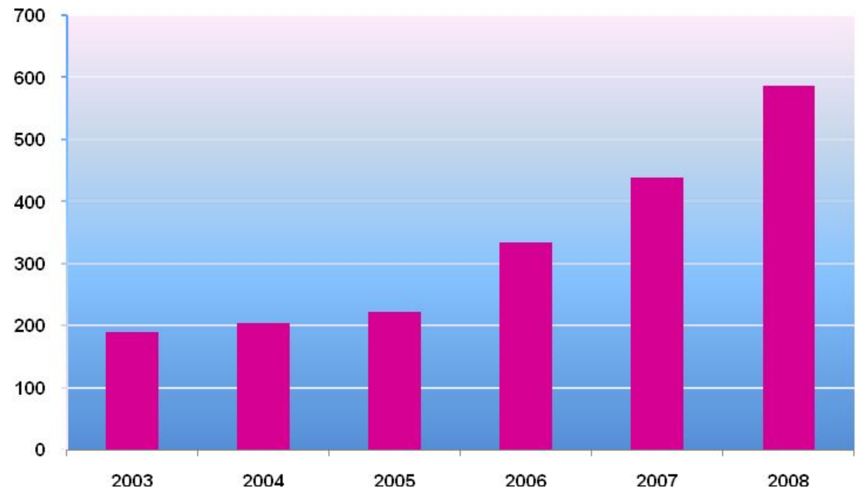

Figure 5.6: Recent Growth of Total NGV Numbers in New Delhi (thousands)

As indicated earlier, the development of the NGV industry in India has largely been driven by mandates issued by the Supreme Court of India. In addition, however, there is a significant financial incentive for conversion of gasoline fuelled vehicles to CNG because of the fuel price differential illustrated in Figure 5.7. The price differential with respect to diesel, however, is very much less and this has led to difficulties in convincing New Delhi bus operators to convert to CNG refuelling.

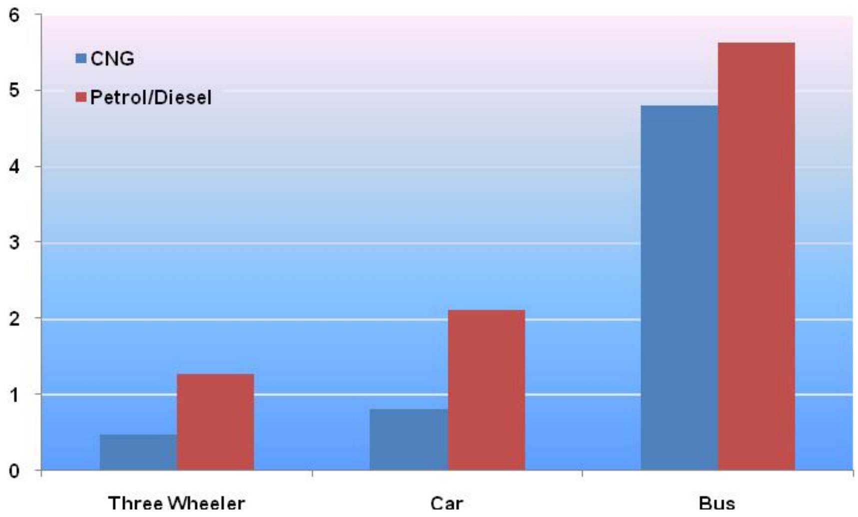

Figure 5.7: Retail Fuel Prices (Rupees/km)

Outcomes

Factors which have influenced the successful introduction of NGVs in India include:

- Government commitment to the program,
- A sustainable fuel price differential advantage of CNG over liquid fuels,
- Availability and development of appropriate CNG technology,
- Appropriate and centralized program management through GAIL and IGL,
- OEM support,
- Good track records for CNG vehicles with respect to both safety and economic performance.

Lessons Learned

The following lessons have been learned in establishing the NGV industry in India:

- It is essential to study the geographical spread of vehicle movement patterns in order to locate CNG refuelling stations appropriately to supply peak fuel demand,
- It is highly desirable that natural gas pipeline distribution infrastructure is in place,

- Continuous supply arrangements for mother-daughter refuelling configurations are required where these are in use,
- Local government and transport authorities must be fully involved in the NGV implementation program,
- Genuine CNG cylinders conversion kits and spare parts must be employed to prevent accidents that frequently result from the use of counterfeit units,
- Suitable standards and codes of practice must be established for CNG conversion and equipment testing,
- Safety and performance standards should be in place, monitored and enforced.

5.4: Autogas in Australia

This case study has been chosen to illustrate an essentially steady state alternative transport fuel industry and how it fluctuates in response to external factors such as price advantage and changes in incentives.

Background

Autogas has been used as an alternative transport fuel in Australia since 1981. The autogas industry has effectively now reached a steady state with half a million vehicles and 3,240 refuelling stations nationwide.

Over the last few years, there have been some small but significant changes in the market, which has generally contracted since reaching a peak in the year 2000.

Drivers

Australia is a large producer and exporter of LPG and its domestic use as an alternative transport fuel is driven by the desire of government both to increase national energy security and to improve air quality in urban areas.

In addition, there is an economic driver as auto gas now accounts for about 60% of the country's LPG consumption.

Responsible Agency/Champion

Currently, responsibility for the autogas industry operation in Australia lies primarily in the private sector, with individual oil companies and LPG distributors taking the lead.

Both the commonwealth and state governments encourage the use of autogas and are generally responsive to the requirements for its ongoing support.

Impediments Encountered

Since the autogas industry in Australia is now established, it can be argued that essentially all of the impediments encountered during its introduction have been addressed and overcome.

It is noteworthy, however, that factors such as the introduction of a goods and services tax (GST) in 2000 definitely constituted an impedimentimpediment to further industry growth. Also, a government proposal to introduce an excise tax on autogas in 2003 generated considerable uncertainty that led to further market contraction.

Chronology and Solutions

Autogas consumption in Australia has remained relatively constant since about 1995, when it exceeded one million tonnes per year. In large part this has been due to the significant incentives offered by both the Commonwealth and State Governments.

The most important incentive is the removal of excise tax from LPG used as an automotive fuel, thereby maintaining the pump price around 40% of gasoline and diesel prices on an energy equivalent basis. This incentive is higher for commercial users since the GST on auto gas is refunded to them.

In addition, the Commonwealth Government offers rebates for the costs of diesel, autogas and other alternative fuels for some categories of commercial users under the Energy Grants Credit Scheme.

Until the end of 2008, the Commonwealth Government also offered grants covering up to 50% of the cost of conversion, or the incremental purchase cost, of buses and other heavy duty commercial vehicles (>3.5 tonnes) to run on either autogas or CNG. A demonstrable minimum reduction of 5% GHG emissions was required and the vehicle had to meet all other contemporary emission limits.

Policies to promote autogas have also been adopted by several Australian States. They include:

- Grants of A$500 for private auto gas conversions or OEM vehicle purchases were introduced in Western Australia in 2000. Western Power Corporation, the state owned electricity company, is replacing up to 200 of its commercial LDVs with autogas vehicles,
- Victoria has mandated that a proportion of new government passenger vehicles having six or more cylinders must be able to operate on autogas,
- New South Wales Government also has a policy of increasing the number of autogas vehicles in its fleet. In February 2004, the NSW Police began to replace up to half of its 1,600 passenger vehicles with OEM autogas vehicles.

Outcomes

The Australian autogas industry has always enjoyed a high level of subsidy and is currently maintained in a more or less steady state situation. It can be argued, however, that the industry may not be fully sustainable since changes to incentive levels, such as have occurred with the introduction of GST in 2000 and the expectation that government would re-impose the excise tax on autogas as announced in May 2003, have clearly had a significant effect on auto gas consumption, as illustrated in Figure 5.8.

Current government plans are to phase in a 12.5% excise tax on autogas over a period of five years, commencing in July 2011. To offset this reduction in incentive, grants of A$1,000 will be made available for each autogas conversion or OEM purchase from July 1, 2001.

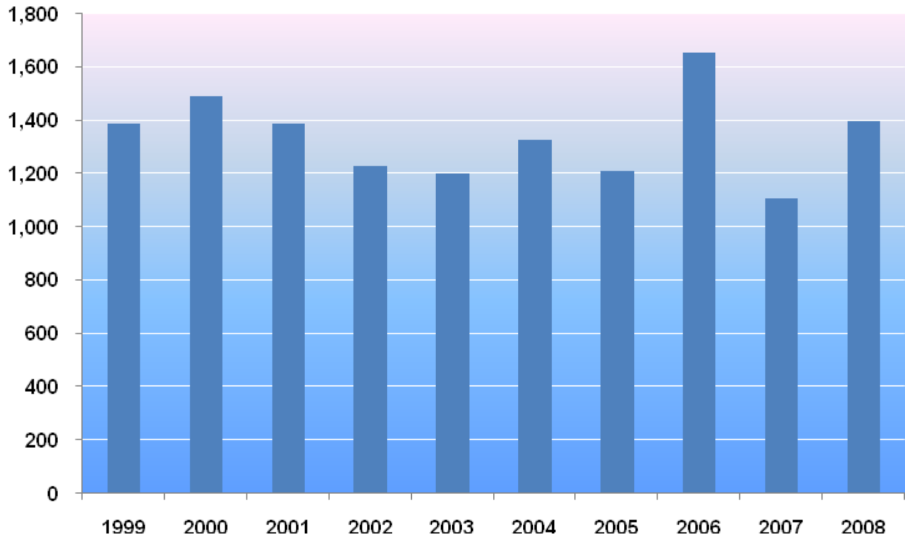

Figure 5.8: Annual Autogas Consumption in Australia (thousands of tonnes)

Lessons Learned

The following lessons have been learned from the autogas industry in Australia:

- Financial incentives have proved very effective in getting the market established,
- The market appears very sensitive to changes in the level of subsidy even though there is still ample advantage available to autogas vehicle users. Indeed, the level of incentive available in Australia would be more than sufficient to initiate a very rapid uptake of autogas in a developing country where the differential fuel saving constitutes a significant fraction of family income,

- The industry illustrates the apparent fact that any reduction in incentive level by government is seen by consumers as a withdrawal of support and results in a loss in confidence. What this means is that there is a need for governments to manage any subsides carefully to ensure that the program is sustainable and to avoid its collapse, as occurred in the New Zealand NGV industry.

5.5: Autogas in Japan

This case study has been chosen to illustrate the development and maintenance of an autogas industry by one of the world's largest autogas consumers. Specifically, it has been chosen to illustrate the forces that come into play when the incentives offered for the use of autogas are really only attractive to very high fuel use vehicles.

Background

Japan has one of the largest autogas markets in the world, although consumption has fluctuated between about 1.5 and 1.8 million tonnes per annum over the last ten years as illustrated in Figure 5.9.

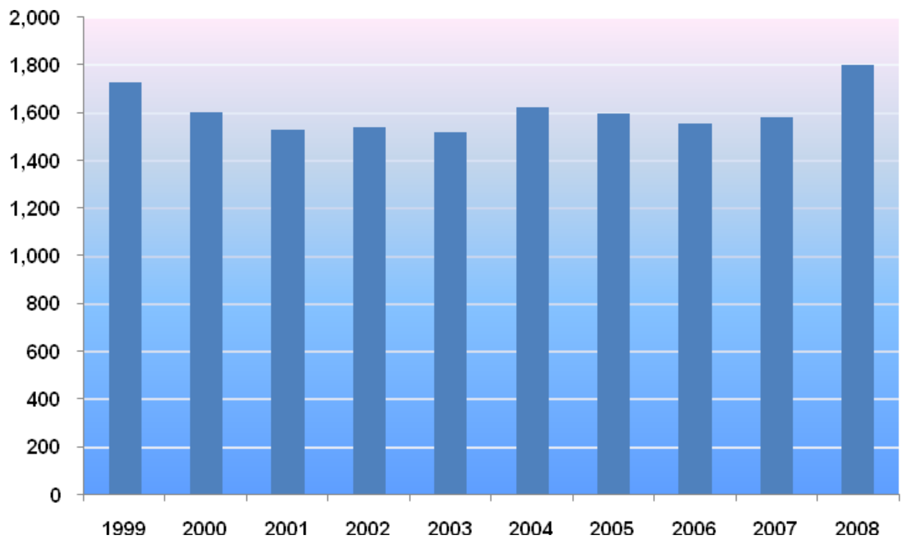

Figure 5.9: Annual Autogas Consumption in Japan (thousands of tonnes)

Autogas makes up about 8% of total Japanese LPG consumption and the country imports about 96% of its requirements.

Very few private vehicles use autogas in Japan. Taxis account for most of its use and light-duty commercial vehicle fleets for almost all of the rest. The number of autogas vehicles in use had been fairly constant at 290,000, but increased substantially in 2008 due to high worldwide fuel prices. Most of the Japanese OEMs (notably Nissan and Toyota) produce dedicated autogas taxis for the national market, selling around 45,000 vehicles per year. There are 1,900 refuelling stations comprising about 4% of all service stations in Japan.

Drivers

Autogas has been in the market for a number of years in Japan and must now be considered as an established and largely sustainable alternative transport fuel. The main driver was originally environmental, with the Japanese government wishing to exploit the clean burning properties of autogas.

There has never really been a national economic driver because the pre-tax price of autogas is almost identical to that of gasoline and much higher than diesel. For current consumers, however, there is a financial driver in that the pump price (including tax) of autogas is currently about 74% that of diesel and 50% that of gasoline.

Responsible Agency/Champion

Originally the Japanese Ministry of Economy, Trade, and Industry (METI) was responsible for the introduction of autogas as a transport fuel. While METI still maintains overall responsibility for the autogas program, much of it is now managed by the Japan LP Gas Association.

Impediments Encountered

Since the autogas industry is now in a sustainable steady state condition, any impediments to its development relate primarily to further penetration of the Japanese automotive fuel market.

Such further penetration is not apparently being pursued by the Japanese government and the current incentive for using autogas as an alternative transport fuel is quite accurately gauged to ensure that autogas uptake remains limited largely to taxi fleets and high mileage commercial LDVs.

Chronology and Solutions

As indicated earlier, autogas consumption in Japan has remained relatively constant, with a small decreasing trend since at least 1990, in which year 1.6 million tonnes of autogas was consumed by Japanese vehicles. In large part this constancy is due to the fact that duties on automotive fuels in Japan have not changed since the late 1990s.

The Japanese government has maintained low excise duties on autogas relative to gasoline and diesel for many years. The duty on autogas is approximately 30% that on diesel and less than 20% of that on gasoline. Lower autogas taxes are, however, partially offset by the higher pre-tax retail price of autogas relative to gasoline and diesel - in spite of the fact that there are no import duties levied on LPG for social reasons since it is widely used for household cooking and heating.

In addition to tax incentives, the Japanese government provides grants that cover either the difference in purchase price between a diesel vehicle or an autogas OEM vehicle or the cost of converting a diesel vehicle to run on autogas. Since April 2003, this grant has been set at 50% of the incremental cost and is capped at US$1,900 for a light-duty van, small truck, or station wagon and at US$2,350 for a normal truck or buses. Local sales tax is also levied at a lower rate (1.1% compared to the usual rate of 3%) for purchases of OEM autogas vehicles with concurrent scrapping of the conventional diesel vehicle it replaces.

Autogas distribution is promoted through grants covering 50% of the cost of both construction and operation of autogas refuelling stations. These subsidies are capped at the equivalent of US$280,000 and US$18,700 respectively. Further government support is evidenced by support for R&D of autogas fuel quality and odorant optimization.

Outcomes

The Japanese autogas market is now well established and has grown substantially in the last two years in response to high international oil prices, which is increasing the price differentials between autogas, gasoline and diesel.

There are now over 300,000 autogas vehicles operating in Japan and 1,900 refuelling sites equal to about 4% of all service stations. Autogas consumption in 2008 reached 1.8 million tonnes up from 1.55 million tonnes in 2006.

Lessons Learned

The following lessons have been learned from the autogas industry in Japan:

- The market size seems to be particularly well controlled in Japan by managing fuel prices through differential excise taxes,
- Autogas is really only attractive to operators of high mileage/high fuel use vehicles such as taxis and LDVs,
- The autogas program has proved to be particularly effective in reducing automobile exhaust emissions from high use inner city vehicles,
- Autogas industry development in Japan has benefited greatly from the availability of purpose built autogas taxis available from most Japanese OEMs.

5.6: Autogas in Korea

This case study has been chosen to illustrate how the world's largest, and one of the longest established, autogas industries is managed in a sustainable manner.

Background

Autogas has a long history of use as an alternative transport fuel in the Republic of Korea. Indeed annual consumption in road transport has exceeded a million tonnes for the last 20 years and there are now approximately 1.8 million autogas vehicles and 1,300 refuelling sites in Korea.

Autogas was originally introduced by the Government of Korea to reduce automobile exhaust emissions from those high mileage vehicles that were contributing substantially to urban air pollution. Government support for autogas has focused primarily on providing a large fuel tax advantage and placing environmental restrictions on the use of diesel vehicles. Demand was boosted in 2000 when the private vehicles, whose use of autogas had previously been restricted, were allowed to use the fuel.

The rapid growth of autogas began to slow around 2002 in response to a change in government policy towards its use. These changes were a result of the improved emissions performance of new gasoline and diesel vehicles relative to autogas vehicles, a preference for NGVs and a desire to boost government revenues by imposing higher autogas fuel taxes.

Autogas excise duties were raised annually over the period 2001–2006 with the result that by 2004 the growth in autogas use had effectively stopped. Significant growth, however, resumed over the period 2005–2008 in response to high international oil prices and somewhat favourable adjustments to the autogas fuel tax. The result is that Korea consumed nearly 4.4 million tonnes of autogas in 2007, an increase of 9% over consumption in 2006 (Figure 5.10).

Drivers

By far the largest single driver for introduction of autogas in Korea was the desire of government to reduce automobile exhaust emissions in cities and towns.

While Korea's ability to meet LPG demand from indigenous production has grown significantly over the past decade, more than 60% of current LPG requirements are imported. Consequently, the use of autogas as an alternative transport fuel does not at present contribute to national self reliance..

Responsible Agency/Champion

The Korean Ministry of Environment was the government agency responsible for implementation and ongoing maintenance of the autogas industry. Since 2000, the Korea

LPG Association has become increasingly active in promoting the use of autogas as an automotive fuel.

Impediments Encountered

As in the case of Australia, the Korean autogas industry is now well established and essentially all of the impediments encountered during its introduction have been addressed and overcome.

It should be noted, however, that the adjustment of excise duties on transport fuels has not favoured autogas, with the result that the market effectively stagnated during the period from 2001–2004 (Figure 5.10)

In addition, lifting the environmental restrictions on the sale of diesel vehicles has effectively acted as a barrier to autogas industry growth.

Chronology and Solutions

As illustrated in Figure 5.10, autogas consumption remained relatively constant over the period 2001–2004 but has increased significantly since then.

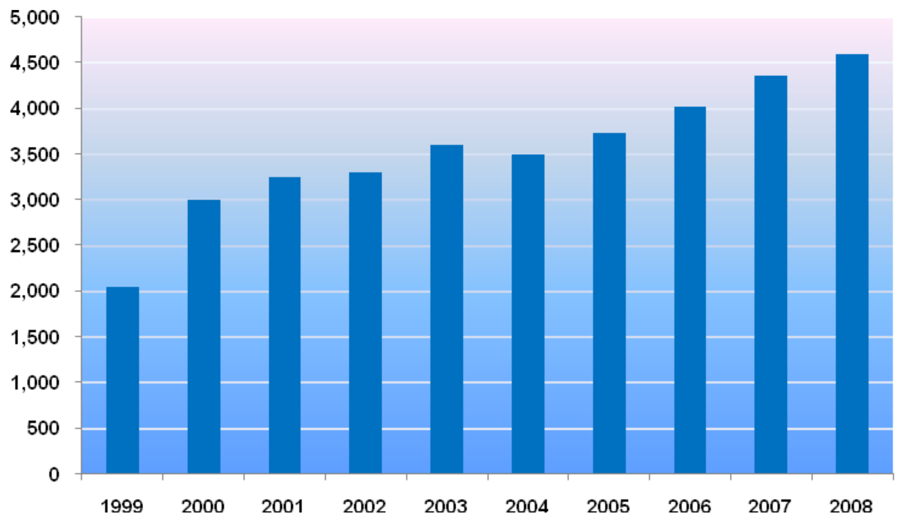

Figure 5.10: Annual Autogas Consumption in Korea (thousands of tonnes)

The Government of Korea exercises control over the autogas industry primarily through the adjustment of the excise tax on gasoline diesel and autogas. The current price ratios of 100% (gasoline) to 85% (diesel) and 50% (autogas) have applied since 2007. Together with high international oil prices, this somewhat increased incentive has contributed to significant growth in autogas consumption over the last few years.

It should be noted, however, that CNG is accorded preferential tax treatment over autogas and grants are offered for purchasing dedicated CNG buses, which are also exempt from the VAT and road tax. The Korean government does not provide grants or tax credits for conversion of light-duty gasoline vehicles to autogas fuelling or for OEM purchases. The Ministry of Environment has, however, sponsored a program to convert 2,000 public diesel fleet vehicles in Seoul, Incheon, and Gyeonggi-do to autogas fuelling.

Outcomes

The Korean autogas market is now well established and has continued to grow – particularly in response to high international oil prices that increase the price differential between autogas and gasoline and diesel.

There are now close to two million autogas vehicles and nearly 1,500 refuelling sites. This means that the number of vehicles per autogas refuelling station is amongst the highest in the world (Table 3.6). However, this is a reflection more of the availability of suitable sites for locating refuelling stations rather than lack of refuelling capability, as the size and configuration of autogas refuelling stations is reported to be adequate.

Lessons Learned

The following lessons have been learned from the autogas industry in Korea:

- The market size can clearly be regulated by government through the management of fuel prices via differential excise and other fuel taxes,
- The incentives offered to autogas consumers have been sufficient to produce nearly 10% industry growth over the past three years,
- The autogas program has proved to be effective in reducing automobile exhaust emissions,
- Governments are favouring the introduction of NGVs to further reduce automobile exhaust emissions from high use inner city vehicles,
- As in Japan, autogas industry development has benefited greatly from the availability of purpose built autogas vehicles manufactured by the leading Korean OEMs.

5.7: Autogas in Thailand

This case study has been chosen to illustrate a situation where strong incentives have resulted in extremely rapid, and possibly unwanted, autogas industry growth.

Background

The autogas industry in Thailand began in the second half of the 1990s in response to concerns about automobile exhaust emissions contributing to heavy pollution in major urban centres. Strong fiscal incentives to use autogas were put in place by government, but these were reduced somewhat in 2001 when government policy shifted towards support for CNG.

Autogas consumption declined over the period 2001–2003, as illustrated in Figure 5.11, before recovering in 2004 and more than doubling between 2005–2008, largely due to high international oil prices that increased the pump price differential between autogas, gasoline and diesel since excise duties on all three fuels has remained unchanged.

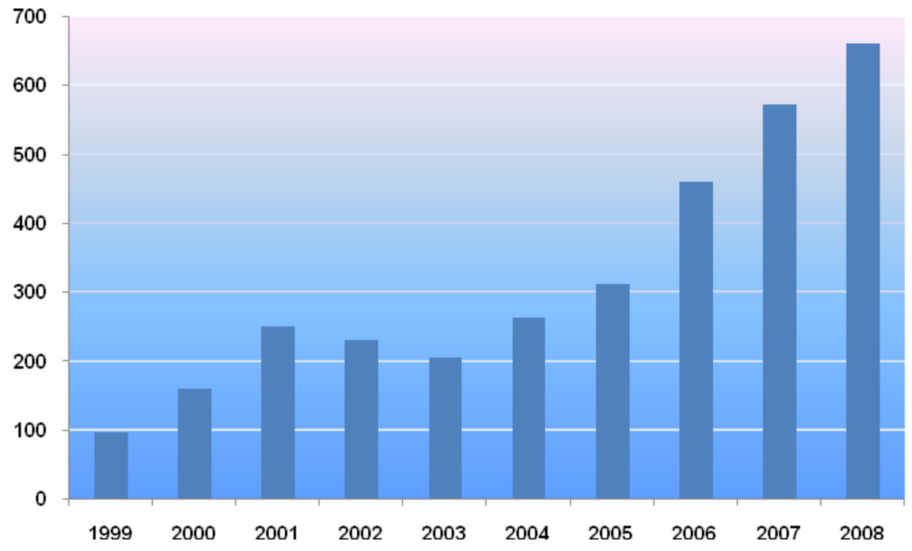

Figure 5.11: Annual Autogas Consumption in Thailand (thousands of tonnes)

Currently, there are about 1.2 million vehicles fuelled by autogas in Thailand and about 355 refuelling sites. It should be noted, however, that at least half of these vehicles are small two- and three–wheelers, so the extremely high ratio of vehicles per refuelling station of 3,380 shown in Table 3.6 is not really as bad as it seems at first sight.

In mid-2008, autogas prices were only about 40% those of gasoline and diesel, making it the strongly preferred transport fuel in the Thai market. As a result, Thailand has had to increase its LPG imports whose delivery to Bangkok is now constrained by infrastructure limitations. The government is, therefore, looking to damp down its burgeoning autogas market.

Drivers

The primary driver for the introduction of autogas as an alternative transport fuel in Thailand was environmental, with the Thai government wishing to lower urban air pollution by reducing automobile exhaust emissions.

Energy security and economics were not issues as Thailand imports more than half of its LPG requirements and subsidises its use as autogas.

Responsible Agency/Champion

The agency responsible for implementing and maintaining the use of autogas is the state owned oil and gas company, Petroleum Authority of Thailand (PTT). The Thai government has been the primary champion of autogas use.

Impediments Encountered

The main impediments to the introduction of autogas were, in common with all other economies, the need to establish the appropriate institutional infrastructure, including standards, industry codes of practice, and regulations for its safe use, and achieving public acceptance of the new fuel.

The autogas industry in Thailand is now well established and further barriers to its growth now relate mainly to the level of financial incentives offered. Currently, this is not a problem as the incentives are high and the uptake of autogas is proceeding rapidly as shown in Figure 5.11.

Chronology and Solutions

Autogas uptake in Thailand peaked in 2001 and then fell off to 2003 when there were an estimated 46,000 vehicles fuelled by autogas and 56 refuelling stations. Most of these vehicles were taxis and motorised rickshaws.

Subsequently, the industry increased rapidly in response to the financial incentives offered and increasing crude oil prices. In 2008, there were about 1.2 million vehicles fuelled by autogas and 355 refuelling sites.

Growth of the autogas industry has been strongly promoted by the fiscal incentives offered by government and its control of fuel prices through a fixed distribution margin. The differential between autogas and gasoline and diesel prices at the pump are now about 40% and 42%, respectively. Commercial users cannot recover sales taxes so the pump price is the same as that for non-commercial users. There are no subsidies for conversion of gasoline vehicles to autogas.

The Thai government has now adopted a policy that favours NGVs over autogas. However, the incentives in place continue to promote the conversion of vehicles to autogas, with a result that it still remains strongly competitive.

Outcomes

Autogas uptake in Thailand is currently growing faster than anywhere else in the world due to its strong competitive advantage and ready acceptance by consumers. It has now reached a point where concerns are being expressed about the increased requirements for LPG imports to supply the autogas industry.

In light of the Thai government's policy to promote NGVs in favour of autogas vehicles, it remains to be seen whether this rampant growth will continue or be curtailed by further government adjustment of fuel prices.

Lessons Learned

The following lessons have been learned from the autogas industry in Thailand:

- The market size can clearly be regulated by government through the management of fuel prices via differential excise taxis and other fuel taxes and levies,
- The incentives offered to autogas consumers have been sufficient to produce nearly 100% industry growth over the past three years,
- The autogas program has proved to be effective in reducing automobile exhaust emissions,
- Some governments are favouring the introduction of NGVs over autogas to further reduce automobile exhaust emission from high use inner city vehicles,
- The use of fiscal measures and fuel price control by government to manage the introduction of an alternative transport fuel must be handled with care to ensure that the market does not become "over cooked" and give rise to potentially adverse national economic outcomes.

5.8: Ethanol in Brazil

This case study has been chosen to illustrate the way in which one of the world's largest and longest alternative fuel users has pursued the introduction of ethanol as a transport fuel.

Background

As a response to the 1973 oil crisis, the Brazilian government began promoting bioethanol as a fuel. The National Alcohol (Pró-Álcool) Program, launched in 1975, was a nationwide program financed by the government to phase out automobile fuels derived from fossil fuels, in favor of ethanol produced from sugarcane.

The decision to produce ethanol from sugarcane was based on the low cost of sugar at the time, the existing idle distillation capacity at the sugar plants, and the country's ample tradition and experience with this feedstock. The first phase of the program concentrated on production of anhydrous ethanol for blending with gasoline.

After testing in government fleets, Brazilian automobile manufacturers modified gasoline engines to support hydrous ethanol characteristics. Changes were made to the compression ratio, the amount of fuel injected, materials that would be incompatible with ethanol, spark plugs suitable for dissipating heat and installation of an auxiliary cold-start system that injected gasoline from a small tank in the engine compartment.

Six years later, around three quarters of Brazilian passenger cars were manufactured with ethanol engines.

By the late 1980s, there were more than four million cars and light trucks, representing one third of the country's motor vehicle fleet, running on pure ethanol. At this point, ethanol production and sales of ethanol-only cars tumbled due to several factors. First, gasoline prices fell sharply as a result of the 1980s oil glut. The inflation adjusted real 2004 dollar value of oil fell from an average of US$78.2 in 1981 to an average of US$26.8 per barrel in 1986.

Also, by mid-1989 a shortage of ethanol fuel supply in the local market left thousands of vehicles in line at gas stations or out of fuel in their garages. At the time, ethanol production was tightly regulated by the government and both gasoline and ethanol fuel were subject to fixed producer prices. As a complement, the government provided subsidies to guarantee a lower ethanol price at the pump compared to gasoline, and consumers were promised that ethanol prices would never be higher than 65% the price of gasoline.

International sugar prices increased sharply at the end of 1988 and the government did not set the sugar export quotas. Consequently, production shifted heavily towards sugar. This resulted in an ethanol supply shortage as the real oil price parity cost of ethanol production was around US$45 per barrel.

Ethanol production stagnated at 12 billion litres and could not keep pace with the increasing demand required by the growing ethanol-only fleet and the Brazilian government began importing ethanol in 1991. Simultaneously, the government began reducing ethanol subsidies, thus marking the beginning of the industry's deregulation and the gradual extinction of the Pró-Álcool Program.

In 1990, production of ethanol-only vehicles fell to 10.9% of the total car production as consumers lost confidence in the reliability of the ethanol fuel supply, and began selling their vehicles or converting them back to gasoline fuel (Table 3.11).

Confidence in ethanol-powered vehicles was restored with the market introduction of flexible fuel vehicles, which started in 2003 (Table 3.11). A key innovation of the Brazilian flex technology was avoiding the need for an additional dedicated sensor to monitor the ethanol-gasoline mix, which had made the first American E85 flexible fuel vehicles too expensive. Brazil is now making FFVs that can use CNG, E25, E85 and gasoline.

Drivers

The primary drivers for the Brazilian ethanol industry were economic, and the needs to increase energy security and reduce environmental air pollution in major urban areas.

The Brazilian government provided three important initial drivers for the ethanol industry. These were:

- Guaranteed purchases of ethanol by the state owned oil company, Petrobras,
- Low interest loans for agro-industrial ethanol producers,
- Fixed gasoline and ethanol prices such that hydrous ethanol sold for 59% of the government-set gasoline price at the pump.

Responsible Agency/Champion

The government has always been the key motivator and champion of the automotive ethanol fuel program in Brazil.

Responsibility for its implementation was largely in the hands of Petrobras (the state owned oil company), which owned and operated most of the refuelling stations. The OEMs responded to both the government and market requirements by producing ethanol blend compatible vehicles, dedicated E100 vehicles, and FFVs.

Impediments Encountered

The automotive ethanol fuel industry in Brazil encountered the usual impediments associated with the introduction of a new alternative transport fuel, *viz.* lack of refuelling infrastructure, the need to develop institutional infrastructure (standards, industry codes of practice, regulations and their administrative infrastructure) and lack of consumer confidence.

Chronology and Solutions

The chronology of development of the Brazilian ethanol fuel market has already been outlined in the background section of this case study. Solutions to the impediments encountered were largely overcome by issuing government mandates and leaving the responsible parties to accommodate.

The Brazilian government mandated a number of ethanol blends with gasoline, fluctuating between 10% to 22% from 1976 until 1992 (Table 3.9). A federal law was passed in October 1993 establishing a mandatory blend of 22% anhydrous ethanol (E22) for the entire country. This law also authorized the executive to set different percentages of ethanol within pre-established boundaries and since 2003 these limits have been fixed at a maximum of 25% (E25) and a minimum of 20% (E20) by volume.

Since 1993 the government has set the percentage ethanol blend according to the results of the sugarcane harvest and the levels of ethanol production from sugarcane, resulting in blend variations even within the same year.

Outcomes

Since July 2007, the mandatory blend of ethanol in gasoline has been 25% of anhydrous ethanol and 75% gasoline or E25.

Meanwhile, flexible fuel vehicles (FFVs) have entered the market in large numbers, as shown in Table 3.11. FFVs made up 73% of Brazilian car sales in 2004, and reached 87.6% in July 2008. This rapid adoption of the flex technology was facilitated by the fuel distribution infrastructure already being in place, as around 27,000 filling stations countrywide were equipped with at least one ethanol pump by 1997. By October 2008, the number had reached 35,000 fueling stations.

The latest innovation of the Brazilian flexible-fuel technology is the development of flex-fuel motorcycles. Besides the flexibility in the choice of fuels, the main objective of the flex-fuel motorcycles has been to reduce CO_2 emissions by 20%. Savings in fuel consumption on the order of 5% to 10% are also expected. These flex-fuel motorcycles are expected to be launched in the market by 2009.

Lessons Learned

The following lessons have been learned from the establishment of ethanol as an alternative transport fuel in Brazil:

- The effectiveness of government mandates in creating rapid responses to government policies,
- The ability to change policies and mandates for ethanol fuel requirements in response to rapidly changing economic conditions,
- The effectiveness of program implementation by the national oil company under government mandate,
- The importance of the early establishment of an extensive refuelling network and institutional infrastructure. This enables very rapid changes to be made in ethanol blend formulations,
- Engagement of a national automotive manufacturing industry to respond to national needs,

5.9: Ethanol in the USA

This case study has been chosen to illustrate the way in which the world's largest alternative fuel consuming economy has pursued the introduction of ethanol as a transport fuel.

Background

The first fuel ethanol plant in the USA was built in Nebraska by the US Army in the 1940s. The ethanol was used as fuel by the Army and for regional blending but essentially none was sold commercially until the late 1970s when blends containing up to 10% ethanol came into increasing use as the government responded to the agricultural lobby to subsidize fuel ethanol production using several different fiscal measures.

Demand for ethanol fuel produced from corn (maize) was spurred by the banning of MTBE as a gasoline octane enhancer in about 20 states by 2006 and a 2005 decision refusing legal protection for MTBE producers opened a new market for ethanol fuel as its primary substitute. Corn growers responded rapidly and by 2006 about 50% of the gasoline used in the USA and more than 85% of Hawaii's gasoline contained ethanol in different proportions.

The number of ethanol compatible vehicles capable of using E10 has grown rapidly. Most cars on the road today in the USA can operate on blends up to E10. In addition there were 1,921 E85 refuelling stations and 7.3 million flexible-fuel fehicles (FFVs), capable of using any combination of ethanol and gasoline from 0 to 100%, in service by the end of 2008. The growth of ethanol consumption and the number of FFVs in use are illustrated in Figure 5.12.

Drivers

There are a number of drivers for the use of ethanol as a transport fuel in the USA. These, and their relative importance have changed over the years but many still apply.

The earliest driver was probably economic as Midwestern farmers and commercial interests lobbied the federal government to provide subsidies for ethanol production from corn to provide economic revitalization in rural communities. Today, this is manifest more as a desire to develop new markets for agricultural products.

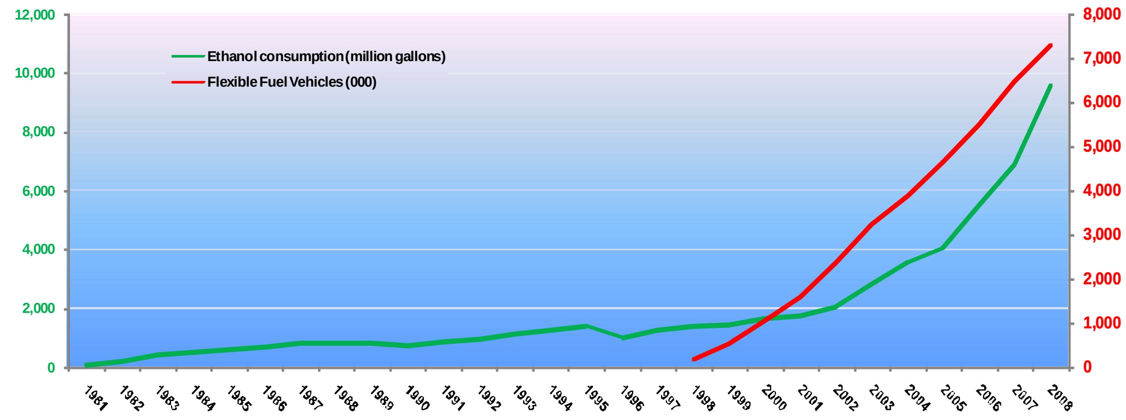

Figure 5.12: Growth of Fuel Ethanol Consumption and FFV Fleet Numbers in USA

Development of the fuel ethanol industry was given added impetus by the emergence of strong environmental, economic, and geo-political drivers. Thus, the value of ethanol as a gasoline oxygenate, used either directly or as a chemical feedstock, was greatly increased when the use of methyl tertiary butyl ether (MTBE) for this purpose was abandoned. High international crude oil prices and the desire to increase energy security by reducing dependence on imported oil have recently been important industry drivers. Fuel ethanol has also been driven in the marketplace by a series of mandates from federal, state and city governments, together with a number of fiscal incentives.

The growth in FFVs illustrated in Figure 5.12 has been driven primarily by the need to meet CAFE requirements and is not directly correlated with fuel ethanol consumption.

Responsible Agency/Champion

At the start, the responsible agency was probably the US Department of Agriculture (USDA), while the project champion was the US corporate agricultural and ethanol lobbies, which are still champions today.

Based on the requirements of the Clean Air Act in 1970 and its 1990 amendments, responsibility for promoting the fuel ethanol program moved to the US Environmental Protection Agency (USEPA). In 1992 the Energy Policy Act (EPAct) mandated certain fleets to acquire AFVs and the US Department of Energy (USDoE) became increasingly involved as a responsible agency.

In effect, those government agencies responsible for implementing and administering particular legislation applicable to fuel ethanol introduction each become responsible for those parts of the program that they administer.

The key legislative acts that mandate and promote the introduction of fuel ethanol in the USA are:

- The Clean Air Act, 1970 and amendments, 1990,
- The Energy Policy Act (EPAct), 1992 and amendments, 2005,
- The Alternative Motor Fuels Act, (1998 & 1992),
- The Energy Independence and Security Act (2007).

Impediments Encountered

In the early stages of introducing ethanol as a blend, the main barriers related to making vehicles and the fuel distribution infrastructure compatible with ethanol use.

A major restriction hampering sales of E85 flex vehicles or fuelling with E85 is the limited infrastructure available to sell E85 to the public, as by October 2008 there were only 1,802 gasoline filling stations selling E85 to the public in the entire USA.

Chronology and Solutions

The US federal and state governments have addressed the impediments to implementation of ethanol as an alternative transport fuel primarily by issuing mandates to which fuel suppliers and the automotive industry have to respond. In this way, responsibility for performance is given to those industry stakeholders who are best able to achieve the outcomes sought.

To this end, the U.S. Congress passed the Energy Independence and Security Act (2007), which mandates an increase in the use of biofuels, including ethanol, through the year 2022, in a new Renewable Fuel Standard (RFS).

In addition, however, the federal government has supported the introduction of ethanol, both as a blend and as E85, by offering several fiscal incentives. These have, over time, included:

- Exemption of 10% ethanol/gasoline blends from the 4¢/gal federal gasoline excise tax,
- Provision of 10% investment tax credit for biomass-ethanol conversion equipment,
- A loan guarantee program for ethanol production facilities,
- Extension of the excise tax exemption through 1992,

- An income tax credit of 40¢/gal for ethanol fuel use,
- A tariff on imported ethanol fuel (currently 54¢/gal)
- Banning gasoline marketing practices that discourage the use of ethanol/gasoline blends,
- Raised gasoline excise tax to 9¢/gal,
- Increased excise tax exemption for 10% ethanol/gasoline blends to 5¢/gal,
- Raised the excise tax exemption for 10% ethanol/gasoline blends to 6¢/gal and the ethanol income tax credit to 60¢/gal,
- Enacting CAFE credits for AFV production,
- Raising the gasoline excise tax to 14.1¢/gal,
- Reducing the excise tax exemption for 10% ethanol/gasoline blends to 5.4¢/gal and the ethanol income tax credit to 54¢/gal,
- Extending the ethanol fuel tax incentives through 2000,
- Establishing a small ethanol producers income tax credit of 10¢/gal,
- Extending the ethanol excise tax exemption to 5.7 and 7.7 ethanol/gasoline blends (at proportionate rates),
- Establishing requirements for AFV purchases by certain vehicle fleets,
- Raising gasoline excise tax to 18.4¢/gal,
- Extending ethanol tax incentives through 2007,
- Reduced amount of incentives to 5.1¢/gal by 2005.

To someone who is not well acquainted with the fuel ethanol industry in the USA, this long list of government actions may seem confusing. It is intended to be so because it helps illustrate the fact that several different federal agencies have pursued their own legislated agendas for promoting the introduction of ethanol.

More importantly, however, it is intended to illustrate the "hands on" policy of the federal government, and also state governments, in guiding the introduction of ethanol as an alternative transport fuel in the United States.

E85 FFVs are now becoming increasingly common in the Midwest, where corn is a major crop and is the primary feedstock for ethanol fuel production. Also, the US government has been using FFVs for many years. By 2008, almost any type of automobile and LDV is available in the market with the flex-fuel option, including sedans, vans, SUVs, and pickup trucks.

Outcomes

There is now a large concentration of E85 stations in the Corn Belt states, led by Minnesota with 357 stations, followed by Illinois with 189, Wisconsin with 118, and Missouri with 112. Only seven states do not have E85 available to the public. These are Alaska, Hawaii, Maine, New Hampshire, New Jersey, Rhode Island, and Vermont. Alcohol fuel prices vary by location with some being more than 30% less than regular gasoline. In other places, alcohol fuels are more expensive than gasoline.

The Energy Policy Act of 2005 requires the federal government's fleet of vehicles capable of operating on alternative fuels to be operated on these fuels exclusively, unless a waiver is granted if the alternative fuel is not reasonably available, or if the cost of the fuel required is unreasonably more expensive than gasoline. The federal vehicle fleet consists of 650,000 vehicles, of which 121,778 are AFVs, mostly FFVs.

As of January 2008, three states - Missouri, Minnesota, and Hawaii - require ethanol to be blended with gasoline motor fuel. Florida has mandated such blends by the end of 2010. Many cities are also required to use an ethanol blend due to non-attainment of federal air quality goals.

The main constraint for a more rapid expansion of E85 availability is that dedicated storage tanks at filling stations are needed at an estimated cost of US$60,000 each.The number of gas stations offering E85 is expected to double over the next year as service stations are being offered incentives from government and ethanol industry grants up to $30,000 for the costs of retrofitting pumps and tanks for E85 fuel. Unfortunately, this does little to offset the cost of installing pumps and tanks for E85 at an estimated $200,000 per station.

A recent development in the expansion of E85 filling stations is Wal-Mart's announcement that it will possibly sell E85 at its 385 gas stations countrywide. Wal-Mart along with its popular division, Sam's Club, has a partnership with Murphy Oil Corp., which operates more than 9,000 gas stations in Wal-Mart parking lots. Should they decide to follow through with plans, Wal-Mart has the potential to be the single largest retailer of E85 in the nation. Grocery retailers in Texas are also beginning to sell E85 at some fuel stations.

By mid-2008, there were more than seven million E85-compatible vehicles on U.S. roads, though actual used of E85 fuel is limited, not only because the ethanol fuelling infrastructure is limited, but also, as found by a 2005 survey, 68% of American FFV owners were not aware they owned an E85 FFV.
The Renewable Fuels Association counts 113 U.S. ethanol distilleries in operation and another 78 under construction, with capacity to produce 11.8 billion gallons within the

next few years. The Energy Information Administration (EIA) predicts that ethanol consumption will reach 11.2 billion gallons by 2012, outstripping the 7.5 billion gallons required in the Renewable Fuel Standard that was enacted as part of the Energy Policy Act of 2005.

The expanding ethanol (and biodiesel) industries provide jobs in plant construction, operations, and maintenance, mostly in rural communities. According to the Renewable Fuels Association, the ethanol industry created 154,000 U.S. jobs in 2005 alone, boosting household income by $5.7 billion. It also contributed about $3.5 billion in tax revenues at the local, state, and federal levels.

Lessons Learned

The following lessons have been learned from the establishment of ethanol as an alternative transport fuel in the United States:

- The effectiveness of government mandates in creating rapid responses to government policies,
- The ability to change policies and mandates for ethanol fuel requirements in response to changing economic conditions,
- The importance of the early establishment of an extensive refuelling network and institutional infrastructure,
- Engagement of the national automotive manufacturing industry to respond to national needs,
- The way in which multiple responsible agencies perform their legislative duties so that incentives for ethanol introduction are promulgated according to their individual agendas,
- The strong "hands on" management and guidance of fuel ethanol introduction by both federal and state governments.

5.10: Biodiesel in Thailand

This case study has been chosen to illustrate the ease of introducing a fuel that is compatible with conventional petroleum and thus can be blended into the diesel pool with negligible functional impact on the driving public.

Background

Palm oil is the main feedstock for biodiesel production in Thailand, although some used cooking oil is also employed.

Total crude palm oil output is 1.3 million tonnes per year, of which 800,000 tonnes is used in the food sector. Of the 500,000 tonnes used in non-food businesses, 420,000 tonnes are now needed to make B2. At least 600,000 tonnes would be required to make B5. The government plans to expand palm oil cultivation area by 400,000 hectares during the next 5 years.

The biodiesel industry in Thailand is still in its infancy. However, it is growing rapidly and B2 is now available at all stations throughout the country. In greater Bangkok, 976 stations offer B5. The total consumption of biodiesel is still small compared to regular diesel. Diesel consumption in 2007 was about 22 billion litres, of which 400 million litres, or about 1.8%, was made up of biodiesel whose introduction is now proceeding quite rapidly.

Drivers

There are several drivers for the introduction of biodiesel in Thailand. Primarily, these include the desire to reduce oil imports and carbon emissions. The Thai government is planning to displace at least 20% of its vehicle fuel consumption with renewable energy such as ethanol and biodiesel within the next five years. Biofuels are also seen by the government as an opportunity for rural development and export.

Responsible Agency/Champion

The biofuels program in Thailand was originally initiated by the Royal Thai Government (RTG). Responsibility for its implementation, however, now lies with the Department of Alternative Energy Development and Efficiency (DEDE).

The sale of biodiesel as an alternative transport fuel is currently the responsibility of two state owned oil companies, PTT Public Company Limited (PTT) and Bangchak Petroleum Public Company (BCP).

The Energy Policy Management Committee maintains oversight of the biodiesel program on behalf of the RTG and, in effect, champions the program.

Impediments Encountered

It is reported that the biodiesel market is currently constrained by the lack of clearly defined incentives for biodiesel investment and the need for further land for palm plantations. The introduction of biodiesel in the market place, however, has been effectively seamless as biodiesel is compatible with conventional diesel and is handled using the same distribution system by the state owned fuel distributors.

Chronology and Solutions

Biodiesel production in Thailand was 58,000 million litres in 2007. Currently, there are nine biodiesel plants with a total production capacity of 655,000 million litres annually. This is equivalent to about 3% of Thailand's current diesel consumption.

In addition to expanding the land area available for palm oil production, the RTG plans to encourage palm plantations in nearby Laos, Cambodia and Myanmar on a contract-farming basis. If this palm oil expansion succeeds, biodiesel production could reach 3.1 billion litres per year by 2012, which is equivalent to 10% of total diesel demand. However, currently high rubber prices are likely to discourage the replacement of old rubber trees with palm trees. Jatropha, which can be grown on marginal land, is seen as an alternative feedstock for biodiesel production in Thailand and one plant intends to use it.

Outcomes

In January 2005, the Thai government announced the Strategic Plan on Biodiesel Promotion and Development. The plan aims to displace 10% of diesel consumption in 2012 by increasing palm oil cultivation and promoting community-based and commercial biodiesel production.

A B2 mandate was introduced in February 2008 and B5 and B10 mandates are planned for introduction in 2011 and 2012, respectively.

Current estimates of biodiesel production costs indicate that production from palm oil costs US$0.86/litre and from cooking oil US$0.68/litre. This means that biodiesel derived from palm oil is more expensive than conventional diesel. However, adjustment of the excise and municipal taxes and contributions to the petrol and conservation funds with respect to those for conventional diesel means that the biodiesel retail price is slightly less than that of diesel.

Lessons Learned

The following lessons can be learned from Thailand's experience of introducing biodiesel:

- Well focused government policy to promote the introduction of alternative transport fuel can greatly facilitate their ease of introduction,
- Overall coordination of activities carried out by several different government agencies is clearly beneficial,
- The introduction of an alternative fuel that is compatible with conventional petroleum is comparatively simple since it does not require significant modification of the infrastructure necessary for fuel handling and distribution,

- Similarly, public acceptance is not normally a problem since no vehicle modification is needed and individual consumers are not impacted personally by the new fuel.

5.11: Synthetic Gasoline in New Zealand

This case study has been chosen to illustrate the introduction of an alternative transport fuel that is compatible with conventional petroleum-derived fuels. The concept was that synthetic gasoline would be blended into the gasoline pool with negligible functional impact on the driving public.

Background

The introduction of CNG as an alternative vehicle fuel in New Zealand was driven partly by the oil shocks of the late 1970's and partly by the availability of surplus natural gas that the government had contracted under a take-or-pay agreement to develop the Maui gas field.

In 1974, New Zealand was importing more than 90% of its transport fuel (4.5 million tonnes) and, as a trading nation, was greatly affected by the rise in oil prices at that time. The off-shore Maui gas field had been discovered in 1969 and a decision was made in 1972 to develop the field for electricity generation. The growth in electricity demand, however, was well below the forecast levels so an amount of 54 PJ/year of gas was earmarked for the production of synthetic hydrocarbon transport fuels.

The Motonui Synthetic Fuels Plant was completed on time and under budget in 1986. Using Mobil Methanol to Gasoline (MTG) technology, it produced 2,000 tonnes/day of 93 RON synthetic, equivalent to 36% of New Zealand's gasoline demand at that time. In addition, the condensate extracted from the gas feedstock was refined into gasoline and diesel to make up a combined contribution of 25% of total transport fuel demand in 1986.

Drivers

By the late 1970s, New Zealand had experienced shortages in conventional fuels which resulted in car-less days and rapidly increasing fuel prices. Being remote from the sources of crude oil supply, the New Zealand government saw the need to improve its energy security position and move towards national self reliance. This fitted well with government goals of improving the economy and increasing employment and these factors, taken together, provided strong drivers for the production of synthetic fuels from indigenous resources. Air pollution and emissions were not significant drivers at that time.

Responsible Agency/Champion

The New Zealand Synthetic Fuel Plant was essentially a government initiative. In 1979, the government established the Liquid Fuels Trust Board (LFTB) charged with making

New Zealand independent from imported transport fuels. One of the options identified very early by the LFTB and recommended to government was to use natural gas from the Maui Field to make synthetic transport fuel. This was accepted by government and both the Prime Minister (who was also the Minister of Finance) and the Minister of Energy became champions.

The LFTB recommended that the Mobil Gas-to-Gasoline (GTG) process be employed and this led to an early partnership between the government and Mobil Oil, which became shareholders in New Zealand Synthetic Fuels Corporation (Synfuels), the company responsible for project establishment.

Synfuels then effectively became the responsible party and contracted top international engineering companies for both the planning and construction phases.

The synfuels plant was operated by Mobil, which carried the project technical risk, whereas the product was sold to the New Zealand government, which carried the market and financing risk.

Impediments Encountered

In principal, the project was faced with significant impediments. There was no historical commercial experience of the Mobil MTG part of the process, as this was the first full commercial scale plant of its kind ever built.

In addition the legislation for establishing a project on this scale was inadequate. There were problems to be overcome in dealing with local Maori interests and environmental concerns and there was significant opposition from NGOs.

It was decided to pre-assemble much of the plant in Japan and ship it to New Zealand in units. However, the plant is located 16 km from the nearest port and the road infrastructure necessary to carry pre-assemblies weighing in excess of 500 tonnes was inadequate.

Chronology and Solutions

Before committing to the Mobil MTG technology, the LFTB worked with Mobil to establish a small demonstration plant that worked almost exactly as predicted. Given the enhanced confidence in the technology, the government passed enabling legislation that "fast tracked" the project through the approval processes.

Following approval, work was immediately done to improve the inadequate infrastructure (road) and useful engagement with stakeholders, such as local Maori and NGOs, was established. One of the outcomes of this engagement was relocation of the plant effluent outfall originally planned for disposal 900 metres off shore to be re-routed through the existing nearby Waitara sewerage outfall.

The world's first commercial synthetic fuels venture was financed from one of the largest non-recourse loans ever raised on the euro-dollar market on a project loan basis. The facility was for a total of US$1.7 billion including a standby facility of US$500 million in case of cost over-runs. The reasons behind the corporation's success in raising such a large loan lay in the determination of its shareholders to formulate a bankable proposition.

The people who were associated with the design and engineering of the project concentrated on eliminating any technological or construction risks, while those involved in negotiating the loans found ways to cover the risks that remained. Emphasis was placed not only on finding optimum solutions but also on finding solutions that would work in changing circumstances in a constantly changing world.

Because the New Zealand Government, rather than New Zealand Synthetic Fuels Corporation, owned the natural gas feedstock the government had to give an assurance that the supply of gas would be continued until at least the project capital cost and debt servicing were recovered. Production risk due to inefficient management and operation of the plant was minimised by contracting plant management to Mobil, which had the experience and resources to do a competent job.

The New Zealand Government carried the market risk for the project since it paid the New Zealand Synthetic Fuels Corporation a processing fee for gas-to-gasoline production. This risk was addressed by the government determining that synthetic gasoline would have a priority on the New Zealand market with gasoline from crude oil providing the balance.

Outcomes

The New Zealand Synthetic Fuels plant was definitely a technical success and it exceeded its design capacity of around 2,000 tonnes/day of synthetic gasoline by approximately 18% once de-bottlenecking had been undertaken following commissioning. Despite the original plans, the synthetic gasoline product was sold almost exclusively overseas because of its high value as a refinery blendstock. Indeed, it is possible that no synthetic gasoline ever found its way into the New Zealand gasoline pool.

Following the fall in international crude oil prices in January 1986, synthetic gasoline became uneconomic to produce and the MTG section of the plant was mothballed. The plant still continued to operate, but as a methanol plant producing 4,400 tonnes/day of "wild" methanol (17% water content), which was further distilled to produce chemical methanol. In the late 1980s, the synfuels plant was sold into the private sector and is now owned by Methanex Corporation.

The New Zealand synfuels plant is widely considered to be an economic disaster brought about by the fall in crude oil prices and it became a political football during New Zealand's elections in 1987 following the fall in oil prices. It should be remembered, however, that by selling synthetic gasoline overseas New Zealand was able to achieve a major reduction in its balance of payments and this was an important factor in the nation's economic recovery after 1987.

Lessons Learned

The following lessons can be learned from the New Zealand synthetic gasoline experience:

- A project can be progressed very rapidly and efficiently when championed by senior ministers and government agencies,
- Enabling legislation is likely to be required to expedite a project of this magnitude in an economy that has little previous experience of such projects,
- Government backing and its assumption of the market and financial risks were key factors in engaging Mobil as a project partner capable of assuming the technical risk,
- Despite the original plans for achieving energy security, economics ultimately controlled the way in which the synfuels plant was operated. Thus the synthetic gasoline product achieved a higher value when sold overseas and the plant was effectively reconfigured when the economics of producing the methanol intermediate outweighed those of producing synthetic gasoline,
- Introduction of the synthetic gasoline product into the market was seamless and was accomplished as part of the everyday activities of the oil companies without intruding on public awareness.

5.12 Electric Vehicles in China

This case study has been chosen to illustrate the introduction of an alternative transport fuel that is driven primarily by market forces rather than financial incentives provided by government.

Background

Over the last few years, China has focused on domestically produced electric scooters, bikes, cars, and buses. As illustrated in Figure 5.13, sales of electric bikes and scooters have increased dramatically since 2000 and reached an estimated 25-30 million in 2008.

These vehicles are now preferred by commuters who previously relied on bicycles, mass transit or gasoline fuelled scooters. In Shanghai, Beijing and several other large cities, gasoline powered scooters are being phased out because of the pollution they produce.

Figure 5.13: Growth of Electric Vehicles in China (millions)

Electric bicycles, such as those depicted at a local charging outlet in Figure 5.14, now make up 10-20% of all two-wheeled vehicles on roads in many major cities throughout China.

Drivers

The main drivers are environmental and energy security. The objective of the Chinese government is to reduce chronic smog in urban areas (two thirds of which comes from tailpipes) and to curb rapidly rising oil imports.

In addition there is an economic driver through export opportunities for Chinese-built electric scooters, which are already being sold in the USA.

Figure 5.14: Electric Scooters Being Recharged at a Public Facility

Responsible Agency/Champion

While the Government of China clearly supports the uptake of EVs, there does not appear to be any one government agency that has been assigned responsibility for their promotion. Rather, the government has announced its policy of reducing urban air pollution and has apparently limited its involvement to establishing standards, codes of practice and regulations to govern the rapidly emerging industry.

In a number of cities, urban officials effectively administer the local policies and ordinances championed by their city governments.

Impediments Encountered

The impediments encountered in introducing EVs in China relate primarily to the speed at which introduction is occurring.

National regulations limit the weight of E bikes to 40 kgs and the speed to 20 kms per hour but manufacturers routinely flout the weight limit and vendors often alter the motor's governor, allowing the vehicles to travel at 35-40 kms per hour (Figure 5.15)

There are also concerns that batteries are not being recycled safely. This is a particular problem because low grade lead-acid batteries are widely used and they have to be changed, on average, once a year. The much superior lithium-ion batteries, which have much longer lives, are not yet widely used in China because of their higher cost.

It has been reported that the speed of introduction of EVs in China has outstripped the establishment of institutional infrastructure at this time and this could lead to a lowering of consumer acceptance, which is currently very high.

Figure 5.15: Typical Electric Bike Widely Used in China

Chronology and Solutions

As shown in Figure 5.13, the growth of EVs in China has been phenomenal. This has been due in part to the fact that China has a well established bicycle culture, competitive pricing and recently introduced policies that allow E bikes to use regular bicycle lanes. In some cities, there have been bans on the production of new two-stroke gasoline fuelled vehicles since 1996.

E bikes in China cost between US$200 and $300 depending on size, quality, and battery type. However, in the highly competitive market for bike manufacturers there is currently no incentive to install lithium-ion batteries that may increase the vehicle cost by as much as 50%.

Outcomes

Despite the comparatively short history of electric vehicles, the rapid growth of the EVsmarket in China means that it is now well established. Most importantly, the EV industry has become established without government fiscal incentives and largely in response to natural market forces. The likelihood of its being sustainable is, therefore, high since there is no need for phasing out government support that usually leads to a significant reduction in consumer confidence and acceptance.

Lessons Learned

The following lessons can be learned from the introduction of EVs in China:

- A project can be progressed very rapidly and efficiently when championed by the government and promoted by government agencies,
- Provided the initial vehicle purchase costs and fuel prices are right, an alternative transport fuel will effectively introduce itself without government assistance,
- In China, government involvement in the introduction of EVs seems to have been limited to an announcement of policy and restrictions placed upon gasoline and diesel fuelled vehicles,
- There was no apparent need for coordination of activities between different parts of government,
- Strong commercial competition, which has been the main market driver, has enabled vehicle costs to be made very attractive to consumers.

5.13 Hybrid Electric Vehicles in the USA

This case study has been chosen to illustrate the very rapid growth in the numbers of HEVs in response to active management and the provision of incentives by government.

Background

As indicated in Table 3.19 earlier, the growth of HEVs in the USA has been extremely rapid and is forecast to continue. Annual sales of HEVs in 2006 were about 250,000 and this number is expected to reach nearly 800,000 in 2012. Currently the market share of HEVs in the USA is about 2.2%.

Drivers

The primary driver for the introduction of HEVs in the USA is environmental since HEVs have significantly lower exhaust and GHG emissions than conventional gasoline and diesel fuelled vehicles. In addition, HEVs provide a degree of energy security since the electricity is generated from domestic primary energy resources and there are economic drivers relating to the cost of securing oil supplies and the potential for export of HEVs.

The market is driven largely by the fiscal and financial incentives put in place by both federal and state governments and by the regulations promulgated to increase the attractiveness of AFVs in general, and HEVs in particular, by comparison with conventional gasoline and diesel vehicles.

Responsible Agency/Champion

As in the case of ethanol, as discussed in Section 5.9, the government agencies responsible for the introduction of HEVs are now the US Environmental Protection Agencies (USEPA) and the US Department of Energy (USDoE), each of which is acting in response to their requirements to administer the legislative acts for which they are responsible.

It should be recorded that the current president of the United States and some state governors, several federal senators and congressmen and their state counterparts have become champions of alternative transport fuels.

Impediments Encountered

Impediments to the uptake of HEVs relate primarily to the extra cost of purchasing an HEV. An HEV currently costs about US$5,000 more than a conventional vehicle and the payback period is likely to be around eight years, which is not particularly attractive to most consumers.

In addition, HEVs represent a new technology and vehicle manufacturers take time to recover R&D costs and to optimise their production and profit chains so as to achieve lower production costs.

Chronology and Solutions

The HEV industry in the United States commenced in the late 1990s with vehicle sales reaching 10,000 units in 2000 (Table 3.20). This had risen to 260,000 by 2006 and there are now over 1 million HEVs currently in service.

The reason for this rapid growth is several fold, but is due primarily to the fact that HEVs enjoy all the benefits accorded to alternative transport fuels in the considerable number of legislated measures that have been enacted in the USA. These are covered in Section 4.4.10 of this report.

Outcomes

The HEV market in the USA is now well established but relies heavily on fiscal and financial incentives made available by federal and state governments so is not yet fully sustainable. The number of HEV models available in the market, however, is projected to grow substantially through 2015 and this will boost HEV sales.

Despite its anticipated growth the HEV percentage share of the 2015 car market is expected to remain within single digits, thus limiting their desirable energy and environmental impacts. Nevertheless, by 2015, HEVs may be expected to have a quantifiable positive impact on the local air quality in urban areas.

Lessons Learned

The following lessons can be learned from the USA experience in introducing HEVs:

- As in the case of FFVs, government mandates and fiscal and financial incentives have been very effective in achieving rapid introduction of HEVs,
- Engagement of the national automotive manufacturing industry by government,
- The way in which several different responsible government agencies promote alternative transport fuels and their production while following their individual agendas as prescribed by the legislative acts for which they are responsible,
- The strong "hands on" management and guidance of HEV introduction by both federal and state governments.

6. Implementation Requirements

The preceding chapters discussed international experiences in the implementation of various alternative transport fuels. It is clear that a wide range of issues needs to be considered if an alternative transport fuel program is to be successfully implemented on a sustainable basis.

The matrix presented as Figure 6.1 provides a conceptual framework of the policy issues and measures that are needed to implement a successful alternative transport fuels program on a commercial scale.

The horizontal axis of the matrix identifies the areas in which policy decisions must be made and actions taken in order to achieve successful introduction of an alternative transport fuel. They are:

- Standards, industry codes of practice, and regulations,
- Economic and financial considerations,
- Market creation,
- Education and training,
- Information and public relations

The vertical axis of the matrix identifies the stakeholders in an alternative transport fuels program who will be affected by the policy outcomes and actions. These are:

- Vehicle owners,
- Fuel producers and suppliers,
- Refuelling station owners,
- Vehicle equipment manufacturers and suppliers,
- Vehicle conversion equipment installers,
- Refuelling station equipment suppliers and installers,
- National and local government agencies.

Table 6.1: Policy Matrix for Implementation of Alternative Fuels

Policy Issues	Standards, Codes and Regulations	Economics/ Financial	Education and Training	Market creation Creation	Information/ Public Relations
Applicability	**All Fuels**	**All Fuels**	**Gas, Liquid Biofuels, Electricity**	**Gas, Liquid Biofuels, Electricity**	**Gas, Liquid Biofuels, Electricity**
Stakeholders					
Vehicle Owner	International or National Standards Codes and Regulations	Acceptable payback period or Appropriate rate of retun on vehicle investment.	Familiarisation on vehicle purchase. Familiarisation or training on vehicle refuelling.	Incentives: grants, low interest loans, tax breaks, fuel price guarantee, Government fleets.	Government/Industry promotion and PR. Industry Assocs User groups
Fuel Producer/ Supply Company		Fuel Production and Sales. Appropriate return on infrstructure	Staff training on prodn, distn equipt installation, refuelling incidents.	Fuel producer and supply company vehicles to be alternative fuel	Fuel producer and supply company promotions.
Refuelling Station Owner		Appropriate return on filling station investment.	Management and staff training on equipt and refuelling. Safety training. Metric compliance.	Incentives eg low interest loan, third party investment Promotion to vehicle owners and fleets.	Government/Industry promotion and PR. Refuelling station industry Assocs. Incident reporting
Vehicle Equipment Supplier		Appropriate markup on imported equipment Local manufacture eg under licence	Staff training on equipt installation Safety training. Vehicle owner familiarisation	Incentives eg import duty rebate, local prodn incentive JVs w third parties (fuel supply Cos)	Sales promotion on PR etc by other parties eg Govt Incident reporting
Vehicle conversion equipment installers		Appropriate charges to vehicle owner for installation	Staff training on vehicle equipment/ installation, Safety & Technician training	Incentives eg low interest loan, grant, third party leasing	Sales promotion based on PR etc by other parties eg Govt Incident reporting
Refuelling equipment supplier and installer		Appropriate markup on equipment and installation Local manufacture eg. under licence	Staff training on station equipment design and installation Training for Installers, Owners, Safety.	Incentives eg import duty rebate, local prodn incentive JVs, eg. Fuel Cos Station owners,	Sales promotion based on PR etc by other parties eg Govt Refuelling station industry Assocs
National and local Government agencies	Regulatory and inspection framework and implementation	Establish Incentives eg tax, loans, grants, infrastructure support	Set up Regulatory Framework, Training regulators/inspectors	Establish Incentives eg tax, loans, grants, with Industry Assocs.	Coordinating body w all Stakeholders PR, info sharing fora.

The matrix does not attempt to rank the importance or relevance of each policy measure, which will, of course, vary considerably with the type of alternative fuel involved. For instance, market creation is not needed for synthetic hydrocarbons since it is the same as the existing market for gasoline and diesel. The fuels to which each policy area applies are indicated in Figure 6.1.

In the following sections, each policy area is discussed in terms of how it affects each stakeholder group and the measures required to ensure the ongoing satisfaction and engagement of each group with both the implementation program and the new industry as it matures. Failure to do so may result in non-achievement of targets set for the implementation program or, possibly, its complete failure.

6.1: Standards, Codes and Regulations

Vehicles operating on roads need a system of standards, codes of practice and regulations to ensure that they are safe in all phases of operation - principally moving and refuelling.

There are existing standards, industry codes and regulations that provide specifications for much of the equipment and facilities on vehicles and the way in which that equipment operates. Most of these apply to gasoline and diesel fuelled vehicles. Additional standards, codes and regulations are needed for alternative transport fuel use and for the production, storage, distribution and fuel measurement systems required.

For some fuels, existing standards and regulations will be quite adequate for the alternative transport fuel (e.g. natural gas pipeline network regulations and those fuels that are compatible with conventional gasoline and diesel).

Standards and Industry Codes of Practice

Normally, standards and industry codes in practice do not have any legal status in their own right. In many cases, however, the associated regulations, which do have legal status, make reference to a standard, thereby making the standard legally binding.

In some cases, however, regulations and standards may differ for a variety of reasons, such as improvements in the understanding of the particular technology that is the subject of the regulation, differences between different countries, and the difference in time between the writing of the standard and the promulgation of the regulation.

Most national standards associations are members of the International Standardization Organization (ISO) and often simply adopt the international standard as their national standard. In other cases where there is no international standard for a new technology, it is necessary for the country standards association to write a national standard in order to allow the new technology to be implemented safely at the time it is required in that country.

Conditions vary from country to country and unfortunately for some alternative fuels and technologies there is a confusing array of national and international standards, each with a different set of requirements. This makes it expensive for manufacturers to provide product to a number of different countries, particularly in relation to equipment testing that needs to be undertaken to verify that the equipment meets the standard applicable in the purchasing country. CNG cylinders are a good example of this. A New Zealand standard NZS5454, originally prepared in the 1980s when New Zealand first started its CNG program, was published in 1989. This was subsequently adopted or adapted in other countries. It was not until 2000, however, that the international standard ISO14239 was finally published.

The task of actually writing standards is normally carried out by a group of experts representing knowledge of the technology, equipment, the operation of vehicles and refuelling and other relevant issues. Ideally, all stakeholders should be involved. In the case of a new fuel, some of the knowledge may be either scarce or inadequate. It is customary, therefore, for standards to be reviewed at appropriate intervals of time (e.g. every five years) so that the operational experience gained can be incorporated into a new version of the standard.

By their nature, standards tend to be conservative because they are concerned with safety. However, this imposes costs on vehicle and refuelling station owners. In general, a greater level of experience can enable changes to be made to the standard and thereby reduce costs.

Regulations

Regulations are the legally binding rules that govern industry practice in response to legislated requirements. They give effect to the issues identified in the standards and may differ between economies due to the wide range of conditions encountered.

For some alternative transport fuels, especially liquids, the need for new regulations is comparatively minor and relates primarily to the storage and dispensing of the fuel. In other cases, such as for high-pressure or liquefied gases, a comprehensive range of regulations is needed to ensure safe operation of the vehicle and its refuelling facilities.

Qualified people are needed for inspections and enforcement of regulations such as:

- Inspection of the vehicle at the time it is converted to run on the alternative fuel,
- Inspection of the refuelling station and its fuel dispensers,
- Inspection of the fuel metering system,
- Fire and safety inspections related to the new fuel and its delivery to the refuelling station,
- Investigation of accidents and incidents involving a fuel other than petrol or diesel.

The last point is particularly important as the issues surrounding accidents and incidents may give rise to a need for regulations to be modified to improve the overall level of safety of vehicles operating on alternative transport fuels. Existing inspectors accustomed to investigating petrol and diesel related accidents may not be well qualified to deal with alternative transport fuels. A typical reaction is to err on the side of safety and to unnecessarily impose costs on both vehicle and fuel station owners.

The section of Table 6.1 Policy Matrix that relates to standards, industry codes of practice, and regulations is reproduced here as Table 6.2 for ease of reference.

Table 6.2: Requirements for Alternative Fuel Standards, Codes and Regulations

Vehicle Owner	Fuel Producer/ Supply Company	Refuelling Station Owner	Vehicle Equipment Supplier	Vehicle conversion equipment installers	Refuelling equipment supplier and installer	National and local Government agencies
International or National Standards, Industry Codes of Practice and Regulations						Regulatory and inspection framework and implementation

Private Sector Stakeholders

For private sector stakeholders, successful implementation of most alternative transport fuels is strongly reliant on the availability of the standards, industry codes of practice and regulations. For most alternative fuels, international standards are available or are being developed. Some of these have been published for many years and are well proven.

Ideally, economies should, by reference, adopt these standards as their national standards with such modifications as are deemed necessary to accommodate local conditions. Any subsequent changes to the international standards will then automatically be incorporated into the national standards.

Even where international standards are not used in a national program, it is vital that high quality, relevant national standards and regulations are available to support the national alternative transport fuel program and to provide a robust framework within which the industry can operate safely and effectively.

International or national standards should be the basis for regulations that control the development of the NGV and autogas industries so that appropriate regulations can be promulgated for fuel containers, vehicle conversion equipment, refuelling stations and fuel distribution systems.

For alcohols and electricity, there is already considerable experience on which safety standards, industry codes of practice and regulations can be based.

For liquid fuels, there has been over a century of experience with gasoline and diesel so existing codes and standards are applicable to synthetic gasoline, diesel, and, in part, to biodiesel.

Many existing standards and codes are relevant or can be adapted for a different fuel.

Even where international standards are not used in a national program, it is vital that high quality, relevant national standards and regulations are available to support the introduction of alternative transport fuels. For those countries that are signatories to UNECE treaties on motor vehicles, UNECE regulations are mandatory.

Government

The role of government is to establish the regulations required to ensure that safe and reliable industries are established and operated effectively for each of the alternative fuels. This needs to be done in cooperation with the national alternative fuels industries to ensure that the regulations are appropriate for the technology, fuel, and local conditions involved. As mentioned above, international standards are well suited to be the basis for national and UNECE regulations.

6.2 Economics and Financial

Initial motivation for the introduction of an alternative transport fuel usually comes from the national government, or in some cases the state government, in response to one or more perceived national benefits. These benefits, or drivers, have been identified for a number of economies in Chapter 5 of this report.

When a decision is made to introduce an alternative transport fuel, individual vehicle owners, fuel suppliers and all other industry participants need to be motivated to engage in the development of the new industry so that it is implemented according to plan. To achieve this, it is usually necessary for the government to offer incentives (mainly financial) to the various stakeholders required to participate in industry development.

Essentially all alternative transport fuels programs have been initiated through government incentives. Great care is needed to design the incentive scheme taking into account local conditions and local economics. For instance, if the incentive is very large, a significant number of vehicle owners may attempt to switch to the alternative fuel without the alternative fuel industry being adequately established to be able to meet the new fuel demand. Inadequate regulations or the availability of qualified technicians may also lag behind demand, thus resulting in unsatisfactory vehicle performance.

Another issue is that the alternative fuels program may be highly successful and require financial support for the incentive scheme far beyond the original intentions of the government.

The section of Table 6.1 Policy Matrix that relates to economic and financial policy considerations is reproduced here as Table 6.3.

Table 6.3: Economic and Financial Requirements for Alternative Transport Fuels

Vehicle Owner	Fuel Producer/ Supply Company	Refuelling Station owner	Vehicle Equipment Supplier	Vehicle conversion equipment installers	Refuelling equipment supplier and installer	National and Local Government agencies
Acceptable payback period or appropriate rate of return on vehicle investment	Fuel Production and Sales. Appropriate return on infrastructure.	Return on filling station investment	Markup on imported equipment Local manufacture eg under licence	Charges to vehicle owners for installation	Markup on equipment and installation Local manufacturer eg under licence	Establish incentives eg tax, loans, grants, infrastructure support.

Vehicle Owners

Any vehicle owner who wishes to change to an alternative transport fuel must make a financial investment. A switch to an NGV is most expensive in terms of upfront cost. Conversion to autogas is less costly. The switch to alcohols may now require a smaller investment with the advent of FFVs, but EVs and HEVs currently have a considerably higher capital cost than existing vehicles, except in China where electric bicycles and scooters are competitive with their gasoline fuelled counterparts. The use of biodiesel and synthetic gasoline and diesel does not require an initial investment by vehicle owners.

In all cases, however, the vehicle owner must have a sufficient financial incentive to ensure recovery of the initial investment through savings in fuel costs.

Government and fuel industry support will be required to achieve an acceptable rate of return, or payback period, for the vehicle owner, particularly in the early stages of the alternative fuel introduction. Typically, a vehicle owner has a target of less than two years to achieve payback on his investment (with either the conversion of an existing petrol vehicle or purchase of an OEM AFV). Early adopters may be looking for an even shorter payback period. Where the fuel is substantially cheaper than petrol or diesel, some owners, such as taxi drivers, will achieve payback in as little as six months.

The government and/or the fuel supply industries need to consider ways whereby this can be achieved. The incentives that have been employed are discussed in depth in Chapter 4 of this report and summarised in Table 4.1. Those that are most widely employed, and are most effective, include grants, low/no interest loans, low taxes on imported equipment and adjustment of fuel taxes to ensure that the alternative fuel is significantly cheaper than its conventional counterpart.

It is likely that these financial supports will need to be modified from time to time as experience in the market place develops and the responses of vehicle owners become apparent in relation to the targets that government or industry has set. Experience indicates, however, that cost reducing incentives to vehicle owners can greatly increase the rate of adoption.

There is a widely held belief that vehicle owners are motivated by the percentage price differential between an alternative transport fuel and conventional gasoline and diesel, and it is frequently claimed that this difference should be around 50%. There are certainly some vehicle owners who are motivated by discounts, but they tend to be in developed economies with considerable exposure to advertising. In developing countries, where incomes are low, many vehicle owners use their vehicle for a living (e.g. taxi drivers) and are motivated solely by how much more money they will bring home to their families if they convert to using an alternative transport fuel.

Table 6.4: Indicative Impacts of Financial Fuel Price Incentives

Alternative Fuel	Economy	GDP/capita US$	Gasoline			Diesel		
			Differential %	Differential USc/litre(e)	% GDP/cap Savings	Differential	Differential USc/litre(e)	% GDP/cap Savings
CNG	New Zealand	20,800	50.0	47.3	**4.5**	54.7	42.4	4.1
	Malaysia	8,900	44.8	20.6	**4.6**	76.6	5.1	1.1
	India	2,600	37.5	40.5	**31.2**	60.9	23.7	**18.2**
Autogas	Australia	27,900	40.2	40.1	**2.9**	42.0	37.2	2.7
	Japan	28,400	58.0	47.1	**3.3**	73.9	23.0	1.6
	Korea	18,700	49.3	44.5	**4.8**	74.2	15.0	1.6
	Thailand	7,200	47.4	26.7	**7.4**	60.8	14.3	**4.0**
E85	Brazil	9,500	59.0	33.6	**7.1**			
	USA	37,800	79.9	32.8	**1.7**			

The difference between the two viewpoints is illustrated by the figures in Table 6.4. These figures have been developed on the assumption that all vehicles travel 20,000 per year and have a fuel consumption of 10 litres/100 km, with gasoline and diesel costs current for Q4 2008. The analysis is intended to be indicative only since annual vehicle mileage and fuel consumption will vary considerably amongst economies and between different vehicle types and use patterns.

It is clear from Table 6.4 that the fuel cost savings achieved as a percentage of annual per capita GDP are significantly different even though the alternative fuel discount percentages are roughly similar. Furthermore, those economies that show a high percentage GDP per capita savings (Brazil, India, Thailand) are exactly the ones in which alternative transport fuel growth has been highest.

Vehicle owners will be motivated in different ways according to their personal perception of the value of the alternative transport fuel to themselves or to the community. Early adopters of the new fuel normally have a different view from later adopters and vehicle owners in different countries have different views.

Fuel Producer/Supplier Company

Fuel supply companies are usually the principal beneficiaries of NGV, autogas or EV programs because they are likely to sell more gas or electricity through their existing pipelines, cable networks or fuel supply infrastructure without substantial additional investment.

Gas supply companies must be closely involved in the development of the refuelling infrastructure whether or not they choose to invest in refuelling stations. At the very least, the gas companies must support refuelling station investors by assisting them with fuel supply decisions. If a fuel supplier does decide to invest in refuelling stations it can do so in partnership with existing refuelling station owners or at new sites where the fuel supply company itself is the principal investor.

For autogas and LNG, the fuel supply company will need to invest in fleets of purpose built trucks and storage tanks to supply refuelling stations.

For liquid alternative transport fuels (ethanol blends, E85, biodiesel), the fuel supply company will need to invest in the infrastructure required to store, blend and transport the fuel. This will involve the use of its own facilities and those at refuelling stations.

In the case of CNG, it may be necessary to extend the gas distribution pipeline network to establish a suitable refuelling station network. Similarly, the electricity supply company may need to strengthen its network to supply the electric load required by compressors.

The gas company may regard such extensions as being profitable in their own right or they may be seen as loss leaders required to develop a satisfactory network of refuelling stations. As discussed in earlier chapters, there are a small number of instances where natural gas is delivered by truck-mounted tube trailers to refuelling stations that are remote from the gas pipeline network. However, such mother-daughter supply arrangements are usually of short duration and are used only as a transition measure to supply gas for an emerging NGV market until additional gas pipelines can be installed.

The fuel supply company can also work with companies who wish to establish private refuelling stations, usually for private fleets such as taxi cabs or buses. In some cases, it may be possible to establish a profitable public refuelling station alongside a private service.

Refuelling Station Owners

All alternative transport fuels require some expenditure at refuelling stations. This might be quite minor when the alternative fuel is a liquid that can be stored and dispensed in equipment that is very similar to that currently in use for gasoline and diesel. In this regard, it should be noted that most underground storage tanks at filling stations leak and therefore contain water. This is not a problem when the tanks are used to store gasoline or diesel as the water does not mix with them and remains at the bottom of the tank. Where alcohol fuels are used, however, new water-tight tankage is frequently required to prevent water mixing with the fuel and sometimes causing phase separation. This significantly increases costs.

For gaseous fuels, the cost is much higher as new storage tanks, compressors, dispensers and control systems are required, with the cost depending on both the fuel and the fuel supply system involved.

Typically, incentives for refuelling station owners are capital grants, low interest loans and reduced taxes on the equipment or construction costs. These incentives may change over time as the alternative fuel market grows and to ensure that it is sustainable. Financial security for refuelling station owners can also be provided through long term fuel purchase contracts with public and private fleet operators.

Local government can support the establishment of alternative fuel refuelling stations by assisting with town planning issues, building consents and transport planning.

Vehicle Equipment Supplier

For most APEC economies, much of the AFV and refuelling equipment will need to be imported. Importers will, initially, have high mark ups to compensate for low volumes and the need to develop a customer support system.

The government or the industry can assist by subsidizing equipment or vehicle costs in order to make the industry viable in the initial stages. Both government and industry need to monitor progress and to adjust prices and support systems as the market grows.

As the industry develops, local equipment manufacture, either under licence or involving locally designed equipment, will commence. Again, there is an opportunity for the government to employ industry support schemes, such as investment grants or employment support, in order to help the alternative fuels and vehicles manufacturing industry to become established.

Vehicle Equipment Installer

Most gaseous fuels programs commence with the conversion of existing gasoline or diesel vehicles. Since this requires qualified mechanics to undertake the conversions, training programs both for the mechanics and for the personnel needed to approve and certify conversions are necessary. Investment is, therefore, required to establish the conversion facilities and for training programs, both of which may need initial support by way of grants and loans. The comments in the preceding three sections regarding the need for financial support are relevant. Both the vehicle owner and the converter need to achieve their appropriate rates of return. For alternative liquid fuels, in most cases only minor changes to the vehicles may be required. Appropriate training programs, with their attendant costs, will be required.

For electricity, purpose built vehicles are required. These are likely to be more expensive than existing vehicles and hence appropriate financial supports by way of grants and loans may be required until EVs achieve a total capital and running cost similar to existing vehicles.

Refuelling Equipment Supplier and Installer

The remarks in the previous Section 6.2.5 also apply to refuelling equipment suppliers and installers. Because these companies need to achieve an adequate return on their investment, the initial stages at least may require some financial support in the form of grants, loans or tax benefits.

Government

Government has a key role in establishing an alternative transport fuel industry and there is virtually no known case where such an industry has been successfully developed without some degree of government support.

The key role of government is to ensure that the various parts of the industry are economically viable. As illustrated by the case studies presented in Chapter 5 of this report, low interest loans, grants, tax rebates, fuel price controls and training support are common methods that are frequently employed, at least in the early stages of a program, to bring this about.

6.3 Education and Training

A wide range of educational and training activities are required for successful and sustainable implementation of an alternative transport fuels program. Some training can best be given by the commercial organizations who supply equipment for refuelling or for the vehicles. More general training can be provided by existing trade schools and colleges, as an addition to their existing curricula.

The section of Table 6.1 Policy Matrix that relates to education and training policy considerations is reproduced here as Table 6.5.

Table 6.5: Education and Training Requirements for Alternative Transport Fuels

Vehicle Owner	Fuel Producer/ Supply Company	Refuelling Station Owner	Vehicle Equipment Supplier	Vehicle conversion equipment installers	Refuelling equipment supplier and installer	National and local Government agencies
Familiarisation on vehicle purchase Familiarisation or training on vehicle refuelling	Staff training on prodn, distn equipt installation, refuelling incidents.	Management and staff training on equipt and refuelling. Safety training. Metric compliance.	Staff training equipt installation Safety training. vehicle owners familiarisation.	Staff training re vehicle equipment/ installation, Safety & Techinican training.	Staff training on station equipment design and installation Training for Installers, Owners, Safety.	Set up Regulatory Framework, Training regulators/ inspectors

Vehicle Owners

The vehicle owner taking possession of an AFV needs a modest amount of instruction to become familiar with the different technology involved. Such instruction is normally provided either by the vehicle converter or by an OEM salesperson using material supplied by the manufacturer and covers vehicle operation, refuelling and certification requirements. Where there is strong government involvement, there may be literature available from government agencies relating to refuelling, vehicle operation, and maintenance.

Fuel Producer/Supplier Company

Staff of the company that produces/supplies an alternative transport fuel needs to be trained in its handling and use to a reasonable level of familiarity. They also need to be aware of the potential for incidents, particularly at refuelling stations, and know the appropriate response mechanisms and reporting requirements.

Refuelling Station Owners

Refuelling station staff must be trained in the safe operation of the refuelling equipment and the procedures for refuelling vehicles. In addition, staff safety training is needed to deal with accidents or equipment failure and the procedures to be followed.

Refuelling station staff must be able to inform vehicle owners of the correct procedures to be adopted when vehicles are being refuelled. They must also be aware of all the requirements of the government agency responsible for certification of weights and measures and to ensure that the customer receives the correct amount of fuel.

Vehicle Equipment Supplier

Equipment suppliers must ensure that their own and other mechanics, whose job it is to install or maintain vehicle equipment, are fully trained. This will include safety training. Such training can be provided by an industry association or through a technical training institution.

Vehicle Equipment Installer

Mechanics undertaking the conversion of vehicles to alternative fuel must be trained on how to install vehicle equipment safely and correctly. Such training is often provided by equipment suppliers and by technical schools. There is a particular need for training in the correct procedures for mounting fuel containers and high pressure equipment, such as pressure relief devices. Mechanics must also be trained in the procedures for certification of AFVs.

Mechanics and panel beaters who are likely to carry out routine maintenance or repair of AFVs need to be trained in the correct procedures and safety issues, even though they may not be involved in equipment installation.

Refuelling Equipment Supplier and Installer

Training is needed for those responsible for the design and construction of refuelling stations. This includes both equipment suppliers and installation contractors. On completion of refuelling station construction the owners/operators must be trained in the correct operating procedures, including safety training and ongoing certification.

Government

It is ultimately the government that is responsible for ensuring that adequate training is available for industry personnel and functions discussed in sections 6.3.1 through 6.3.6, provided either by the industry or national education systems. Industry often provides training relating specifically to a particular task or item of equipment. However, government schools or colleges should provide appropriate training courses for mechanics and technicians.

Training is also required for inspectors and regulators. All alternative fuels require specialized training to ensure that inspectors understand the requirements of both vehicles and refuelling stations. Training is also needed in the procedures that should be followed in the event of an accident.

6.4 Market Creation

Creation of a healthy and sustainable market for an alternative transport fuel is the primary objective of any implementation program. There is now considerable experience in how to achieve this and it is generally agreed that a combination of incentives, such as those listed in Table 4.1, are the key to creating a viable alternative transport fuels market.

The ways in which the incentives listed in Table 4.1 can form part of an overall alternative transport fuels implementation policy such as laid out in Table 6.1 Policy Matrix are summarised in Table 6.6 and discussed in the following sections.

Table 6.6: Policy Requirements for Alternative Transport Fuels Market Creation

Vehicle Owner	Fuel Producer/ Supply Company	Refuelling Station Owner	Vehicle Equipment Supplier	Vehicle conversion equipment installers	Refuelling equipment supplier and installer	National and local Government agencies
Incentives: grants, low interest loans, tax breaks, fuel price guarantee, Government fleets.	Fuel producer supply company and vehicles to be alternative fuel	Incentives eg low interest loan, third party investment Promotion to vehicle owners and fleets.	Incentives eg import duty rebate, local prodn incentive JVs w third parties (fuel supply Cos)	Incentives eg low interest loan, grant, third party leasing	Incentives eg, import duty rebate, local prodn incentive JVs, eg. Fuel CosStation owners.	Establish Incentives eg tax, loans, grants, with Industry Assocs.

Vehicle Owners

Introduction of an alternative transport fuel, such as CNG, LNG, autogas, biofuels or electricity, requires orderly uptake of the new fuel by vehicle owners to ensure market creation and healthy growth. Typically, various incentives are provided by governments, fuel suppliers and equipment suppliers, as discussed in Chapters 4 and 5.

The most common incentives offered to vehicle owners are:

- Grants for vehicle conversion,
- Low/no interest loans for vehicle conversion or OEM vehicle purchase,
- Fuel price guarantees to ensure that the vehicle owner achieves an acceptable payback on investment. (A more sophisticated approach is to include the equipment cost recovery in the fuel price.)

If the government is strongly promoting the alternative fuel program, it can issue a mandate for vehicle conversion or OEM vehicle purchases and should convert as many as possible of its own vehicles to the alternative fuel as appropriate. It should also become involved in advertising and public relations programs.

Fuel Producer/Supplier Company

The fuel producer/supplier is one of the main beneficiaries of an alternative transport fuel program because of the additional product sold. It is appropriate, therefore, that the fuel producer/supplier should provide financial or other incentives to assist in the creation and growth of a new alternative transport fuel market.

It is also appropriate that fuel company vehicles, especially those involved in the supply of the alternative transport fuel, be converted to its use so that the company provides leadership by example.

Refuelling Station Owners

Refuelling stations are the most capital intensive part of the NGV, autogas, biofuels, and, possibly, EV industries. They have a vital role in the initial stages of alternative transport fuel implementation, as vehicle owners must be able to see an adequate network of refuelling facilities (including the potential for home refuelling) when making a decision to switch to an alternative fuel. Consequently, incentives such as government grants, low interest loans, third party investment (e.g. by fuel companies) and opportunities for equipment leasing are required to facilitate rapid development of the refuelling network. A fuel company could also become an importer of refuelling station equipment.

New refuelling station operators need to promote their new service to vehicle owners in the vicinity and work together to publicize the refuelling network and the location of stations.

Vehicle Equipment Suppliers and Installers

The conversion of vehicles to alternative fuel, or the purchase of OEM vehicles, is the most important part of market creation and it is essential that vehicle owners have sufficient incentives to switch to the new fuel.

In addition to the direct incentives for vehicle owners discussed previously, governments can also provide incentives to alternative transport fuels conversion equipment suppliers and installers to reduce the cost of conversion for the vehicle owner. Options include a reduction of import duty, low interest loans, third party leasing and subsidised personnel training and equipment certification. Government can also provide incentives to assist the establishment of local equipment manufacturing capabilities.

Fuel companies can also assist with equipment import by way of joint ventures or the provision of low interest loans; they can invest in AFVs that are leased for high fuel consuming activities (e.g. taxis and city buses). A fuel company may, itself, become an equipment importer and installer.

Refuelling Equipment Supplier and Installer

The growth of an alternative transport refuelling network can be accelerated by reducing the capital cost of refuelling facilities. As in the case of vehicle owners, this can be achieved by providing an incentive directly to the refuelling station owner or indirectly to refuelling station equipment importers.

Options include a reduction of the import duty, low interest loans, third party leasing and subsidised personnel, and equipment certification and training. As in the case of vehicle conversion equipment, governments can also provide incentives to assist the establishment of local equipment manufacturing capabilities.

Importers of equipment can also form joint ventures with other industry players, such as gas companies, oil companies, and refuelling station owners, to facilitate the development of the refuelling network.

Government

The government has a role to provide appropriate incentives to all industry participants to ensure that each performs effectively and efficiently and is appropriately rewarded.

As discussed in Chapter 4 and illustrated in the case studies presented in Chapter 5, government incentives commonly include grants, low/no interest loans, a reduction of taxes and duties, support for local equipment manufacture, regional industry grants, R&D, industry promotion, and involvement in industry associations.

They also include the promulgation of mandates that have been shown to work very well, provided that they are backed up with sufficient financial incentives to ensure that the vehicle owner and other industry participants are not financially disadvantaged.

6.5 Information, Public Relations

Engagement of the motoring public in the introduction of an alternative transport fuel is vital to its successful implementation. Key to this is to keep the public informed about the program and to mount an effective public relations effort to counteract the adverse publicity that normally accompanies the introduction of an alternative transport fuel that impacts upon individual consumers.

The problem does not, of course, arise for alternative fuels such as biodiesel and synthetic gasoline and diesel that can be introduced with little or no impact on the motoring public.

The actions that can be taken by individual stakeholders to disseminate information and engage in public relations initiatives are discussed in the following sections. These are summarised in Table 6.7, which forms part of the overall policy matrix in Table 6.1.

Table 6.7: Policy Requirements for Information Dissemination and Public Relations

Vehicle Owner	Fuel Producer/ Supply Company	Refuelling Station Owner	Vehicle Equipment Supplier	Vehicle conversion equipment installers	Refuelling equipment supplier and installer	National and local Government agencies
Government/ Industry promotion and PR. Industry Assocs User groups	Fuel producer and supply company promotions.	Government/ Industry promotion and PR. Refuelling station industry Assocs. Incident reporting.	Sales promotion on PR etc by other parties eg Govt Incident reporting	Sales promotion based on PR etc by other parties eg Govt Incident reporting	Sales promotion based on PR etc by other parties eg Govt Refuelling station industry Assocs	Coordinating body w all Stakeholders PR, info sharing fora.

Vehicle Owners

Both government and the alternative transport fuel industries need to provide information and to undertake advertising and public relations programs that keep vehicle owners informed to assist in development of the new industry. In some economies, government has taken a leading role in the advertising and promotion of an alternative fuel.

Industry associations need to be provided with full information by both government and industry practitioners about the overall and functional benefits of an alternative transport fuel and how its implementation is progressing so they can provide their members with reliable information.

Problems with vehicle performance, which do occur from time to time, may require a public relations initiative to inform consumers and counteract adverse publicity that is often either largely incorrect or biased.

Fuel Producer/Supplier Company

Fuel producers and supply companies can provide information and engage in public relations relating to fuel and the fuel supply network for which they are responsible.

Refuelling Station Owners, Equipment Suppliers and Installers

It is probably not desirable for refuelling station owners, equipment suppliers and installers to engage in public relations campaigns other than through their industry associations.

Rather, their promotion and information sharing should, ideally, be limited to advertising their products and the location of new refuelling outlets as they come on stream. They should, however, keep their industry associations informed of their perceptions on how the implementation program is progressing and of any problems that arise.

As with any part of the transport industry, accidents and incidents will occur. These need to be reported and investigated by suitably qualified and experienced personnel from the fuel and vehicle industries and the regulatory agencies.

Information sharing amongst refuelling station owners, equipment suppliers and contractors can be facilitated through an alternative fuel industry association.

Vehicle Equipment Suppliers and Installers

The remarks offered in the preceding section apply equally to vehicle equipment suppliers and installers.

Government

The government has a role to collect, evaluate and disseminate information about all aspects of the alternative fuel industry. This can be achieved through information sharing fora and industry associations.

At least in the early stages of introducing an alternative transport fuel, there is a necessary and important role for a coordination committee of some type with membership from both government and all the stakeholders in the industry. Government is the logical leader for such a committee, particularly in the early stages.

7. Implementation Guidelines

Chapters 3 through 6 have covered the experience gained from the introduction of all of the main alternative transport fuels in APEC economies and several non-APEC economies, where their experience is particularly instructive.

This chapter is intended as a toolkit or roadmap that can be used by proponents of an alternative transport fuel program. It summarizes the findings of the earlier chapters in general terms and puts forward some overall guidelines for implementation of alternative transport fuels programs.

7.1 Conditions for Fuel Switching

There are several conditions that need to be considered as prerequisites for the implementation of an alternative transport fuels program. These include:

- The availability of adequate reserves of primary energy (e.g. natural gas, biomass) needed to produce the alternative transport fuel,
- The existence of, or commitment to, a liquid fuel or gas distribution system on a scale that will provide good opportunities for construction of refuelling stations for the alternative fuel in the locations of interest,
- Vehicles that are candidates for conversion to an alternative fuel on a scale that will result in the establishment of a viable commercial market,
- The existence of a regulatory and commercial framework that will allow the alternative transport fuel system to develop in a safe and profitable manner,
- A government that is prepared to champion the introduction of an alternative transport fuel or, at the very least, to be a strong supporter.

It is assumed that commercial scale introduction of an alternative transport fuel involves the equivalent of 10,000 LDVs or 100 HDVs that will use the fuel. A smaller number is considered as a demonstration or prototype.

7.2 Drivers

It should be established at an early stage that there are convincing reasons, or drivers, for introducing an alternative transport fuel. These are usually one or more of the following, as discussed in Section 2.1:

- Reduction of local air pollution and health effects,
- Reduction of GHG emissions,

- Enhancement of energy security and national self reliance,
- Import substitution,
- Economic opportunity value of the alternative transport fuel,
- Mobilisation of an available domestic energy resource,
- Employment creation.

One or more of these drivers should be sufficiently strong to engage the attention of government and its pursuit of alternative transport fuel introduction as a matter of national energy policy.

7.3 Program Management

As recognised in Section 6.5.7, there is a necessary and important role for the early establishment of a program coordinating committee with representation from both government and industry stakeholders.

Government is the logical leader for such a committee, particularly in the early stages, as government agencies are most readily able to commit the resources needed for feasibility studies and implementation planning.

7.4 Feasibility Studies

The first step is to carry out a pre-feasibility study to determine whether a project exists, whether it is likely to be economically viable and how it might be implemented. If the outcome is encouraging, a full feasibility study must be conducted in sufficient depth for the outcome to be the basis for robust recommendations for government action. The following issues should be covered:

- The nature, location, availability and ownership structure of the primary energy reserves required,
- The manufacture or processing of the alternative transport fuel, identifying the technical configuration and evaluating the economics and environmental impacts,
- How the retail sales price of the alternative transport fuel could be set so as to provide a fuel price incentive to switch from gasoline or diesel,
- The configuration of the existing and future transport fuel distribution system and how it might accommodate the introduction of an alternative fuel,

- The design of the alternative transport fuel distribution system, including refuelling station site availability and equipment needs,

- A definition of the existing and likely future vehicle fleet, including vehicle type, motive power, ownership, general traffic patterns and the identification of vehicles most likely to be candidates for alternative transport fuel use,

- An evaluation of current and projected local and global exhaust and GHG emissions with and without fuel switching,

- An assessment of the environmental impacts associated with the production, distribution and use of the alternative transport fuel,

- An assessment of the extent to which the existing regulatory environment will support the safe manufacture, processing, development and maintenance of the alternative transport fuel and its refuelling stations, with identification of additional institutional infrastructure that may be required,

- The extent to which there exists a commercial environment that will facilitate the development of a new industry through equipment imports, local and foreign investment, bank lending and available workforce,

- An assessment of the skill sets and levels of local engineering and transport organisations that are likely to be involved in an alternative transport fuel program and identification of technical training requirements,

- The identification of a potential champion for the alternative transport fuel program - particularly a government champion.

The study will have to determine the likely rate of alternative transport fuel uptake based upon vehicle turnover rates, incentive levels and the availability of refuelling facilities. It will also evaluate the level of government and industry support needed for sustainable development of the alternative transport fuel industry.

Depending on the circumstances, it may be necessary to focus a feasibility study at the regional or city level, as well as at the national level. This would occur, for example, if the alternative transport fuel is available only in a particular region or the reasons for its introduction apply only locally (e.g. reduction of urban air pollution).

7.5 Implementation Plan

If a decision is made to proceed, an Implementation Plan needs to be developed. This will contain recommendations on how the alternative transport fuel industry is to be established. It will cover:

- The production, storage, blending and distribution of the alternative transport fuel,

- The target vehicle fleet,
- The vehicle refuelling station system and network,
- The standards, industry codes of practice and regulations required and the institutional infrastructure needed, including inspection and enforcement capabilities,
- Personnel training, capacity building and R&D requirements,
- The configuration and establishment of government and industry incentives needed to promote and support initial implementation,
- The financing of fuel production, storage and distribution facilities,
- The financing of refuelling station equipment,
- The financing conversion or purchase of OEM AFVs,
- Mechanisms for provision of government support and involvement of all appropriate government agencies,
- An outline plan for promotional activities, including advertising and public relations campaigns,
- Targets for the implementation of key elements of the alternative transport fuel system.

A draft implementation plan should be discussed fully with government including appropriate government agencies and industry stakeholders. The aim is to produce a final plan that will succeed because its components have already been approved, and will be adopted, by all stakeholders and organizations likely to be involved in the alternative fuel introduction and market development.

7.6 Program Initiation

The coordinating/steering committee recommended in Section 7.3 above should be ultimately responsible for initiating implementation, either by delegating to their membership or by contracting consultants to perform specific tasks.

For ease and effectiveness of project initiation, three elements need to be commenced at a very early stage. These are:

- Vehicle and refuelling system demonstration trials,

- Institutional requirements,
- Industry policies and incentives.

All of these are vital to the successful implementation of an alternative transport fuel and all take considerable time to reach fruition.

7.6.1 Demonstration Trials

As shown by the implementation experience and case studies presented in Chapters 3 and 5 of this report, essentially all alternative transport fuel implementation programs have included one or more demonstration trials designed to provide a platform for study and evaluation of issues such as:

- Vehicle driveability, performance characteristics, durability, alternative fuel consumption,
- Fuel distribution and handling requirements,
- Vehicle refuelling and refuelling station requirements,
- Consumer satisfaction.

In addition to gathering information, the conduct of demonstration trials has the advantage of providing the sponsors of the alternative transport fuel program with the opportunity to get further comfort that the initiative will work and their decisions are robust. They also provide the public with an early preview of how an alternative transport fuels industry may operate.

To gain maximum advantage from demonstration trials, several of which may be run in parallel, their design and commencement should be scheduled as one of the earliest elements of the implementation plan.

7.6.2 Institutional Framework

The standards, industry codes of practice and regulations required, and the institutional infrastructure needed, should be identified and established early so as to provide a secure framework within which the fledgling industry can develop. Standards and industry codes of practice, in particular, often take a very long time to put in place.

It is essential that the consumers and private sector stakeholders, in particular, are provided with a high degree of certainty about the market rules so they feel comfortable about investing in a potentially high risk new industry.

7.6.3 Promotion Policies

The configuration and establishment of government and industry incentives needed to promote and support alternative transport fuel implementation should be initiated early because enabling legislation needs to be enacted and regulations written to promulgate the legislation. Both of these activities take time and the market will not begin to develop until incentives and regulations are in place.

7.7 Market Development

Once these things are in place, market forces must be allowed to operate with guidance and occasional assistance from government through the project coordinating committee that should function more like a board of directors as the market develops.

The various management options and actions available to each industry stakeholder are discussed in Chapter 6 and summarised in the policy matrix included as Table 6.1.

Details of the options available for promoting alternative fuel industry growth are discussed in Chapter 4 and summarised in Table 4.1.

The case studies presented in Chapter 5 provide insight to the ways in which different alternative transport fuel markets have developed and the determinants of their development pathways.

It is clear from these case studies that there is no single "right" way to successfully introduce an alternative transport fuel. The ways in which introduction has proceeded in different economies depends both on the type of fuel and the economy involved.

These guidelines are intended to show the many choices that are available.

8. Conclusions and Lessons Learned

The following conclusions and lessons learned are forthcoming from the information presented herein and the lessons learned from the case studies of alternative transport fuels implementation presented in Chapter 5 of this report.

For ease of reference, they are grouped more or less in terms of the categories identified in the implementation matrix presented in Table 6.1.

General

1. We now have many years of experience of introducing alternative transport fuels in a number of economies. Some programs have been very successful, others have not. The important conclusion is the need to learn from the experiences of these programs and, accordingly, to design and implement successful future programs.

2. There is no universal model for the introduction of alternative transport fuels. Different models have been applied in different economies and most have been successful.

3. Developing economies have, on balance, done a better job of introducing alternative transport fuels and creating viable and potentially sustainable industries and markets than their more developed counterparts. This is probably due to the fact that greater financial incentives are available to vehicle owners due to their lower incomes.

4. There is a need to develop a critical mass in order to achieve a sustainable alternative transport fuel industry. Once this critical mass is achieved, industry growth will continue under its own momentum until its market opportunity is reached relative to the price of transport fuels.

5. The introduction of an alternative fuel that is compatible with conventional petroleum equivalents is comparatively simple since it does not require significant modification of the infrastructure necessary for fuel handling and distribution.

6. The introduction of a significantly different fuel requires carefully planning for the development of the infrastructure, particularly the balance of converted vehicles and refuelling facilities at any time in the implementation program.

The Role of Government

1. Governments should ultimately be responsible for initiating, advancing and coordinating the introduction of an alternative transport fuel since national benefits normally.accrue,

2. Involvement of the government is essential for effectively progressing the aims and objectives of an alternative fuels program. Its role is to:

    - Oversee and coordinate alternative fuel industry development,
    - Create and modify, as necessary, appropriate incentive packages,
    - Establish and enforce mandates such as requirements for the conversion of fleet vehicles,
    - Promote and support the creation of appropriate standards, codes and regulations for both AFVs and their refuelling stations,
    - Ensure that appropriate training courses, covering both AFVs and their refuelling, are established,
    - Fund R&D,
    - Provide leadership by example (e.g. early conversion of government vehicles to the alternative fuel),
    - Encourage and support public relations and communications strategies and programs.

3. A new industry needs a champion – preferably in both the government and private sectors. A project can be progressed very rapidly and efficiently when championed by senior ministers and government agencies.

4. Enabling legislation is likely to be required to expedite a major project (e.g. synthetic gasoline production) in an economy that has little previous experience with such projects.

5. The appointment of a national oil company as champion and organiser of an alternative transport fuel program has been shown to be effective as it enables coherent and orderly industry growth.

6. Local government and transport authorities must be fully involved in the implementation of an alternative transport fuel.

7. The overall coordination of activities carried out by several different government agencies is clearly beneficial, although individual pursuit of the legislated agendas of multiple government agencies has also proved effective.

8. Once market forces come fully into play, an alternative transport fuels industry should become self-sustaining and the role of government will be reduced to regulating and administering the market and the industry.

9. Great care must be exercised in decoupling government involvement in a new alternative transport fuels industry until it reaches maturity to guard against a loss of public confidence.

Stakeholder Involvement

1. Successful alternative transport fuels programs have fully involved the key industry stakeholders to ensure that their concerns are addressed.

2. The engagement of a national automotive manufacturing industry in the introduction of an alternative transport fuel greatly expedites market growth.

3. Specific criteria for the successful introduction of an alternative transport fuel include the following:

   - Vehicle owners require a payback of their conversion investment within two years at the most if they are to change to using an alternative fuel,

   - Depot-based fleets are good initial targets for conversion to an alternative transport fuel,

   - An appropriately comprehensive refuelling network should be established at an early stage so as not to inhibit early growth of an alternative transport fuel industry.

Standards, Codes and Regulations

1. Government and industry must collaborate to establish the necessary institutional infrastructure (standards, regulations, training) for the regulation of an alternative transport fuels industry at an early stage of its development.

Economic and Financial Requirements

Incentives are effectively the control mechanism for governments to manage the rate and extent of alternative transport fuel implementation. Specific requirements are that:

- Incentive policies need to be consistent with respect to the vision of the alternative transport fuels industry development program. The strategy and focus should be modified, or incremental, to take account of changing conditions as implementation proceeds,

- Incentives should not be set so high that they result in boom growth whereby converted vehicles are unable to be easily refuelled and are no longer economic to operate when incentives are removed,

- The application of fiscal measures and fuel price controls to manage the introduction of an alternative transport fuel must be handled with care to ensure that the market does not become "over cooked" and give rise to potentially adverse national economic outcomes,

- The need to change policies and mandates in response to changing economic conditions should be exercised with considerable care if public confidence in an alternative fuel is to be maintained.

- Government mandates have been effective in creating rapid responses to Government policies,

- Mandates should always be accompanied by financial and other incentives.

Education and Training

Adequate training and certification must be provided, either by the industry or national education systems, for all mechanics, technicians and inspectors involved in an alternative fuels industry.

Market Creation

1. The complexity and cost of introducing an alternative transport fuel depends primarily on the extent to which a new fuel distribution and delivery system is required and, to a lesser extent, to the need to modify vehicle engines or pay premium prices for purpose built OEM vehicles.

2. Provided the initial vehicle purchase costs and fuel prices are right, an alternative transport fuel will effectively introduce itself under normal market forces.

3. Market size can be quite precisely controlled by managing fuel prices through differential excise and other fuel taxes.

4. Strong commercial competition has been able to lower AFV costs so they become very attractive to consumers.

5. In order that the new alternative transport fuel industry is sustainable, there must be careful planning for decoupling government involvement as the market reaches maturity.

Information and Public Relations

1. The loss of public confidence in an alternative fuel, for whatever reason, can greatly inhibit further industry development, and sudden removal of government support can kill an industry that was otherwise developing well.

2. Any reduction in incentive level by government is seen as a withdrawal of support by consumers.

3. Public acceptance of alternative transport fuels that are compatible with conventional petroleum fuels is not normally a problem since no vehicle modification is needed and individual consumers are not impacted personally by the new fuel.

Glossary of Terms and Abbreviations

The following is a list of terms, abbreviations, and acronyms used in this report and their definitions:

A$	Australian dollars
ACT	Australian Capital Territory
AFV	Alternative fuel vehicle
AIP	Australian Institute of Petroleum
APEC	Asia Pacific Economic Cooperation
ASTM	ASTM International (originally known as the American Society for Testing and Materials)
Bbl	Barrel
Biodiesel	A non-petroleum-based diesel fuel consisting of long chain esters made by transesterification of vegetable oil or animal fat that can be used (alone, or blended with conventional petrodiesel) in unmodified diesel-engine vehicles.
Biogas	A gas produced by the biological breakdown of organic matter in the absence of oxygen
Bi fuel	Vehicle can operate on either of two on-board fuels, eg natural gas or gasoline
BOI	Board of Investment, Thailand
C$	Canadian dollars
CBERA	Caribbean Basin Economic Recovery Act
CBI	Caribbean Basin Initiative
CCC	CNG Coordinating Committee
CH_4	Methane
CI	Compressed ignition
CNG	Compressed natural gas
CO_2	Carbon dioxide
CTL	Coal to liquid
DF	Dual fuel
Dual fuel	The vehicle requires two fuels to operate eg natural gas and diesel as a pilot
DOE	Department of Energy, USA
EPAct	Environmental Protection Act
ETAX	Excise tax
ETS	Emissions trading schemes
EU	European Union
EV	Electric vehicle
EWG	Energy Working Group
FCV	Fuel cell vehicle
FFV	Flexible fuel vehicle
FY	Fiscal year
GHG	Greenhouse gas
GM	General Motors
GTL	Gas to liquid

GVWR	Gross vehicle weight rating
HDV	Heavy-duty vehicle
HEV	Hybrid electric vehicle
HFI	Hydrogen Fuel Initiative
HK$	Hong Kong dollars
IA-HEV	International Association of Hybrid Electric Vehicles
IANGV	International Association of Natural Gas Vehicles
ICE	Internal combustion engine
IEA	International Energy Agency
ISO	International Standardisation Organisation
LCNG	LNG and compressed natural gas obtained from LNG
LDV	Light-duty vehicle
LFTB	Liquid Fuels Trust Board
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MOGD	Methanol to olefins-gasoline-and diesel
MTAX	Municipal tax
MTG	Methanol to gasoline
Mtpa	Million tonnes per annum
NEV	Neighbourhood electric vehicle
NGC	Natural Gas Corporation, New Zealand
NGO	Non governmental organisation
NGV	Natural gas vehicle
NO_2	Nitrogen dioxide
NREL	National Renewable Energy Laboratory, USA
NSW	New South Wales
NZ	New Zealand
$NZ	New Zealand dollar
NZEPCL	New Zealand Energy Planning Consultants Limited
NZERDC	New Zealand Energy Research & Development Committee
OEM	Original equipment manufacturer
OPEC	Organisation of Petroleum Exporting Countries
PEM	Proton exchange membrane
PESTE	Political, economic, social, technical and environmental
PHEV	Plug-in hybrid electric vehicles
PNGV	Petronas NGV Sdn Bhd
PR	Public relations
R&D	Research and development
RCS	Regulations, codes and standards
RD&D	Research, development and demonstration
RM	Recreational motorhome
RVP	Reid Vapour Pressure
SHC	Synthetic hydrocarbon
SI	Spark ignition
SPFC	Solid polymer fuel cell
STP	Standard temperature and pressure
SVO	Straight vegetable oil

TCF	Trillion cubic feet
Th!nk	Brand name for a line of innovative electric cars
TNO	Netherlands Organisation for Applied Scientific Research
Tonnes	Metric tonnes
UHC	Unconventional hydrocarbon
UK	United Kingdom
USA	United States
US$	United States dollar
VAT	Value added tax
WLPGA	World LPG Association

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Appendix A

Natural Gas Vehicles (NGVs) Worldwide

Country	Natural Gas Vehicles		Refuelling stations		Last update
	Total	%	Total	%	
Pakistan	2,000,000	20.91	2,600	17.87	December 2008
Argentina	1,745,677	18.25	1,801	12.38	November 2008
Brazil	1,588,331	16.61	1,688	11.60	December 2008
Iran	846,169	8.85	637	4.38	October 2008
India	821,872	8.59	325	2.23	March 2008
Italy	580,000	6.06	700	4.81	August 2008
China	336,500	3.52	1260	8.66	October 2008
Columbia	269,753	2.82	401	2.76	October 2008
Bangladesh	180,000	1.88	296	2.03	November 2008
Ukraine	120,000	1.25	224	1.54	December 2007
Thailand	117,727	1.23	253	1.74	November 2008
Armenia	101,352	1.06	214	1.47	March 2008
USA	100,000	1.05	816	5.61	September 2008
Bolivia	99,657	1.04	123	0.85	August 2008
Egypt	98,738	1.03	116	0.80	October 2008
Russia	95,000	0.99	224	1.54	October 2008
Germany	64,454	0.67	804	5.53	September 2008
Bulgara	60,255	0.63	70	0.48	October 2008
Peru	54,829	0.57	56	0.38	November 2008
Uzbekistan	47,000	0.49	43	0.30	December 2007
Malaysia	40,248	0.42	101	0.69	January 2008
Japan	35,720	0.37	327	2.25	September 2008
Myanmar (Burma)	22,821	0.24	37	0.25	October 2006
Korea	17,123	0.18	121	0.83	June 2008
Sweden	16,900	0.18	122	0.84	December 2008
Canada	12,140	0.13	101	0.69	December 2007
Takistan	10,600	0.11	53	0.36	December 2007
France	10,150	0.11	125	0.86	March 2007
Chile	8,064	0.08	15	0.10	December 2007
Switzerland	7,122	0.07	112	0.77	December 2008
Kyngystan	6,000	0.06	6	0.04	December 2007
Belarus	5,500	0.06	25	0.17	December 2007
Moldova	5,000	0.05	14	0.10	December 2007
Venezuala	4,200	0.04	124	0.85	November 2008
Austria	3,574	0.04	170	1.17	October 2008
Trinadad & Tobago	3,500	0.04	10	0.07	December 2006
Turkey	3,056	0.03	9	0.06	July 2008
Mexico	3,037	0.03	3	0.02	November 2008
Georgia	3,000	0.03	4	0.03	December 2007
Singapore	2,700	0.03	3	0.02	November 2008
Indonesia	2,453	0.03	9	0.06	March 2008
Australia	2,453	0.03	146	1.00	March 2007
Spain	1,863	0.02	42	0.29	December 2008
Poland	1,700	0.02	30	0.21	December 2008
Czech Republic	1,230	0.01	33	0.23	October 2008
Netherlands	1,110	0.01	21	0.14	December 2008
Latvia	500	0.01	4	0.03	December 2007
Finland	472	0.00	13	0.09	December 2008
Slovakia	426	0.00	7	0.05	December 2008
Greece	416	0.00	1	0.01	December 2007
Portugal	379	0.00	6	0.00	May 2007
United Arab Emirates	305	0.00	2	0.00	March 2007
Belgium	300	0.00	9	0.00	November 2005
United Kingdom	294	0.00	33	0.00	December 2008
New Zealand	283	0.00	14	0.00	March 2007
Serbia	210	0.00	7	0.00	December 2007
Norway	180	0.00	9	0.00	December 2007
Croatia	152	0.00	1	0.00	December 2007
Algeria	125	0.00	3	0.00	October 2004
Hungary	122	0.00	3	0.02	December 2007
Luxembourg	115	0.00	4	0.03	June 2007
Lichtenstein	101	0.00	3	0.02	December 2008
Iceland	77	0.00	1	0.01	December 2007
Nigeria	60	0.00	2	0.01	May 2005
Macedonia	50	0.00	1	0.01	March 2007
Phillipines	36	0.00	3	0.02	February 2006
Tunesia	34	0.00	1	0.01	October 2007
Lithuania	17	0.00	1	0.01	September 2008
Panama	15	0.00		0.00	November 2008
Bosnia & Herzegovina	7	0.00	3	0.02	February 2007
Motenegro	6	0.00	1	0.01	March 2006
Chinese Taipei	4	0.00	1	0.01	April 2005
Mozambique	4	0.00	1	0.01	May 2007
Tanzania	3	0.00		0.00	July 2007
Ireland	2	0.00	1	0.01	October 2008
Dominican Republic	1	0.00	1	0.01	May 2007
	9,563,274	**100.00**	**14,550**	**100.00**	

Appendix B

Incentives for Alternative Transport Fuels

Appendix B1: Renewable Energy Incentives

Country	Feed-in tariff	Renewable port-folio standard	Capital subsidies, grants, or rebates	Investment or other tax credits	Sales tax, energy tax, or VAT reduction	Tradable renewable energy certificates	Energy production payments or tax credits	Net metering	Public investment, loans, or financing	Public competitive bidding
Developed and transition countries										
Australia		*	*			*			*	
Austria	*		*	*		*			*	
Belgium		*	*		*	*		*		
Canada	(*)	(*)	*	*	*			(*)	*	(*)
Croatia	*			*					*	
Cyprus	*		*							
Czech Republic	*		*	*	*	*		*		
Denmark	*				*	*		*	*	*
Estonia	*				*					
Finland					*	*	*			
France	*		*	*	*	*			*	*
Germany	*		*	*	*				*	
Greece	*		*	*						
Hungary	*				*	*			*	
Ireland	*		*	*		*				*
Italy	*	*	*	*		*		*		
Israel	*									
Japan	(*)	*	*			*		*	*	
Korea	*		*	*	*				*	
Latvia	*								*	*
Lithuania	*		*	*					*	

Country	Feed-in tariff	Renewable port-folio standard	Capital subsidies, grants, or rebates	Investment or other tax credits	Sales tax, energy tax, or VAT reduction	Tradable renewable energy certificates	Energy production payments or tax credits	Net metering	Public investment, loans, or financing	Public competitive bidding
Developed and transition countries										
Luxembourg	*		*	*						
Malta	*				*					
Netherlands	*		*	*		*	*			
New Zealand			*						*	
Norway			*	*		*				*
Poland		*	*		*				*	*
Portugal	*		*	*	*					
Romania					*					
Russia			*			*				
Slovak Republic	*			*					*	
Slovenia	*								*	
Spain	*		*	*					*	
Sweden		*	*	*	*	*	*			
Switzerland	*									
United Kingdom		*	*		*	*				
United States	(*)	(*)	*	*	(*)	(*)	*	(*)	(*)	(*)

Country	Feed-in tariff	Renewable port-folio standard	Capital subsidies, grants, or rebates	Investment or other tax credits	Sales tax, energy tax, or VAT reduction	Tradable renewable energy certificates	Energy production payments or tax credits	Net metering	Public investment, loans, or financing	Public competitive bidding
Developing countries										
Algeria	*			*	*	*				
Argentina	*		*	(*)	*		*			
Brazil	*								*	*
Cambodia			*							
Chile			*							
China	*		*	*	*				*	*
Costa Rica	*									
Ecuador	*			*						
Guatemala				*	*					
Honduras				*	*					
India	(*)	(*)	*	*	*		*		*	*
Indonesia	*									
Mexico				*				*		
Morocco				*						
Nicaragua	*			*	*					
Panama							*			
Parkistan			*	*	*					
Phillipines			*	*	*				*	
South Africa			*	*	*		*			
Sri Lanka	*									
Thailand	*		*					*	*	
Tunisia			*	*						
Turkey	*		*							
Uganda	*								*	

Appendix B2: Types of Alternative Transport Fuel Incentives Available, USA

State	Grants	Tax Incentives	Loans and Leases	Rebates	HOV Lane Access	Exemptions from Requirements/Restrictions	Fuel Discounts	Technical Assistance	Totals
Federal US	20	16	6	0	0	1	0	3	46
Alabama	1	0	0	0	0	0	0	1	2
Alaska	0	0	0	0	0	0	0	0	0
Arizona	1	2	0	0	1	1	0	0	5
Arkansas	1	0	1	0	0	1	0	0	3
California	13	0	2	7	1	8	5	1	37
Colorado	1	3	0	1	1	1	1	1	9
Connecticut	3	0	0	0	0	1	0	2	6
Delaware	0	1	0	0	0	0	2	1	4
Dist. of Columbia	0	0	0	0	1	2	0	1	4
Florida	2	1	0	0	1	3	0	0	7
Georgia	0	4	0	0	2	0	0	2	8
Hawaii	0	3	0	0	0	1	0	1	5
Idaho	0	3	0	0	0	0	0	1	4
Illinois	5	0	0	1	0	3	0	3	12
Indiana	3	7	0	2	0	1	1	0	14
Iowa	3	4	2	0	0	0	0	1	10
Kansas	0	5	0	1	0	0	0	0	6
Kentucky	1	4	0	0	0	1	0	2	8
Louisiana	1	2	0	0	0	0	0	1	4
Maine	1	2	2	0	0	0	0	0	5
Maryland	0	3	0	0	0	1	0	0	4
Massachusetts	0	1	0	0	0	1	0	1	3
Michigan	3	4	0	1	0	2	0	0	10
Minnesota	1	1	1	0	0	0	0	1	4
Mississippi	2	0	0	1	0	0	1	0	4
Missouri	3	1	0	1	0	2	0	2	9
Montana	0	8	0	0	0	0	0	0	8
Nebraska	0	3	0	0	0	2	0	0	5
Nevada	1	0	0	0	0	1	0	0	2
New Hampshire	1	0	0	0	0	0	0	0	1
New Jersey	1	2	0	3	1	1	0	1	9
New Mexico	1	4	2	0	0	1	1	2	11
New York	6	3	0	1	1	0	0	3	14
North Carolina	5	5	1	0	0	2	0	0	13
North Dakota	1	6	1	0	0	0	0	0	8
Ohio	6	1	2	0	0	0	0	0	9
Oklahoma	0	5	2	0	0	1	0	0	8
Oregon	0	4	2	0	0	2	0	0	8
Pennsylvania	4	2	2	1	0	0	0	1	10
Puerto Rico	0	0	0	0	0	0	0	0	0
Rhode Island	0	3	1	0	0	0	0	0	4
South Carolina	0	6	0	1	0	2	0	0	9
South Dakota	0	3	0	0	0	0	0	0	3
Tennessee	3	0	1	1	1	1	0	1	8
Texas	5	1	0	3	0	0	1	5	15
Utah	1	1	1	0	1	3	0	1	8
Vermont	0	1	0	0	0	0	0	1	2
Virgin Islands	0	0	0	0	0	0	0	0	0
Virginia	1	3	1	0	1	0	1	2	9
Washington	3	5	1	0	0	3	0	1	13
West Virginia	0	0	0	1	0	0	0	0	1
Wisconsin	2	2	0	1	0	1	0	1	7
Wyoming	0	1	0	0	0	0	0	1	2
TOTALS	106	136	31	27	12	50	13	45	

Appendix B3: Alternative Transport Fuel Incentives for Fuels and Technologies, USA

State	Alternative Fuel - All	Biodiesel	Ethanol	Natural Gas	Liquefied Petroleum Gas (LPG)	Electric Vehicles (EV and NEV)	Hydrogen/Fuel Cells	Blends	Hybrid Electric Vehicles (HEV)	Emissions Based
Federal US	15	35	30	27	27	19	26	15	8	21
Alabama	1	2	2	2	2	1	1	0	0	0
Alaska	2	1	2	1	1	2	1	0	0	1
Arizona	5	6	6	9	10	10	7	0	1	2
Arkansas	2	4	4	4	4	2	2	2	1	0
California	9	14	11	30	18	33	27	1	23	31
Colorado	4	9	9	10	8	6	8	2	4	3
Connecticut	4	5	5	6	4	5	5	1	2	5
Delaware	1	1	1	2	2	1	1	0	0	0
Dist. of Columbia	3	3	3	4	3	3	3	0	1	1
Florida	2	11	13	2	2	4	7	5	1	3
Georgia	3	7	6	7	3	6	4	1	2	2
Hawaii	5	8	11	5	6	6	6	2	2	0
Idaho	0	5	4	2	2	1	1	4	1	0
Illinois	2	15	14	6	5	6	4	7	3	4
Indiana	3	12	17	6	4	4	4	18	2	0
Iowa	4	13	17	6	5	8	5	7	0	0
Kansas	2	7	10	4	4	2	1	1	0	0
Kentucky	3	7	7	6	4	2	1	4	1	0
Louisiana	0	3	7	6	4	4	2	3	2	1
Maine	3	6	8	5	5	5	4	3	0	1
Maryland	1	4	4	1	1	3	1	0	2	2
Massachusetts	3	7	7	5	3	3	3	2	2	2
Michigan	5	11	11	6	6	6	6	7	5	0
Minnesota	3	8	10	4	4	6	4	4	3	1
Mississippi	1	2	2	5	3	1	1	0	1	0
Missouri	3	7	6	5	4	4	4	5	0	1
Montana	2	8	8	4	4	3	2	2	0	0
Nebraska	0	3	4	3	3	2	2	1	0	0
Nevada	3	3	3	5	5	5	4	1	2	2
New Hampshire	2	5	2	2	2	3	2	1	1	1
New Jersey	2	3	3	6	5	6	3	0	4	4
New Mexico	7	12	10	8	7	7	9	2	4	1
New York	6	11	13	16	10	12	12	4	4	2
North Carolina	6	15	14	8	8	7	7	8	4	3
North Dakota	0	9	8	2	2	0	3	5	0	0
Ohio	3	7	6	3	3	2	3	2	0	2
Oklahoma	4	8	10	7	7	7	4	1	1	0
Oregon	5	12	11	7	6	9	7	4	5	5
Pennsylvania	4	8	7	5	4	4	4	0	3	2
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Rhode Island	2	3	2	4	3	5	3	1	1	4
South Carolina	1	10	9	3	4	3	5	5	2	0
South Dakota	0	8	9	1	2	0	0	10	0	0
Tennessee	5	14	10	8	7	6	5	6	4	1
Texas	4	8	8	11	10	7	7	1	1	1
Utah	2	2	2	9	7	8	5	1	1	0
Vermont	3	5	4	4	3	4	3	2	2	4
Virgin Islands	0	0	0	0	0	0	0	0	0	0
Virginia	3	9	6	9	7	7	7	1	1	2
Washington	4	17	13	9	8	11	6	8	6	6
West Virginia	4	4	4	4	4	5	4	0	0	0
Wisconsin	6	13	10	7	7	6	6	4	2	1
Wyoming	0	0	2	1	0	0	0	1	0	0
TOTALS	167	410	405	322	272	282	252	165	115	122

Appendix B4: Laws and Regulations applicable to Alternative Transport Fuels, USA

State	Individual Vehicle Purchaser/Driver	Fleet Purchaser/ Manager	Fueling/ Recharging Station Builder or Operator	Alternative Fuel Producer	Alternative Fuel Dealer	Alternative Fuel Purchaser	Alternative Fuel or AFV Researcher	Electrified Truck Stop Builder/ Operator	AFV Manufacturer/ Retrofitter	Totals
Federal US	10	31	9	16	8	4	3	3	6	90
Alabama	1	1	0	2	0	2	1	0	0	7
Alaska	1	2	1	0	1	1	0	0	0	6
Arizona	9	11	4	1	1	0	0	0	2	28
Arkansas	3	4	1	2	3	3	0	0	2	18
California	30	39	7	5	1	5	7	3	7	104
Colorado	8	10	4	1	2	2	2	0	2	31
Connecticut	3	11	4	2	1	0	1	0	2	24
Delaware	2	4	1	0	1	2	0	0	0	10
Dist. of Columbia	2	3	0	0	0	0	0	0	1	6
Florida	6	10	4	7	5	3	6	0	5	46
Georgia	6	7	4	3	3	4	0	0	1	28
Hawaii	3	4	2	5	4	5	3	0	2	28
Idaho	1	3	2	2	4	4	0	0	0	16
Illinois	5	14	9	5	3	3	2	0	1	42
Indiana	2	9	5	8	7	4	2	0	4	41
Iowa	4	8	7	5	7	1	2	0	0	34
Kansas	4	7	2	3	3	2	0	0	1	22
Kentucky	1	4	2	5	4	4	2	0	1	23
Louisiana	5	8	5	6	2	1	0	0	1	28
Maine	4	7	1	3	1	2	0	0	1	19
Maryland	4	6	0	2	0	1	1	0	1	15
Massachusetts	2	7	1	2	3	2	2	0	1	20
Michigan	1	4	3	4	4	1	4	0	2	23
Minnesota	5	8	3	4	3	5	1	0	0	29
Mississippi	3	4	0	1	3	3	0	0	1	15
Missouri	6	10	4	4	2	5	0	0	0	31
Montana	4	5	2	5	3	2	1	0	2	24
Nebraska	3	5	1	2	3	2	0	0	0	16
Nevada	4	6	0	0	1	1	0	0	0	12
New Hampshire	3	6	1	1	1	1	0	0	0	13
New Jersey	6	10	1	0	0	1	0	0	2	20
New Mexico	5	12	6	4	2	4	3	0	2	38
New York	8	18	10	2	3	2	2	0	3	48
North Carolina	2	9	8	7	7	4	0	1	2	40
North Dakota	0	0	4	6	5	3	2	0	0	20
Ohio	1	5	3	3	2	4	1	1	3	23
Oklahoma	5	6	6	4	1	1	2	0	1	26
Oregon	7	10	2	4	3	2	1	0	1	30
Pennsylvania	5	8	4	3	2	5	1	0	3	31
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Rhode Island	5	9	0	1	1	0	0	0	0	16
South Carolina	4	8	1	4	3	1	2	0	0	23
South Dakota	0	2	1	7	5	8	0	0	0	23
Tennessee	4	11	8	7	6	5	2	0	0	43
Texas	9	15	4	3	3	3	1	0	1	39
Utah	9	12	2	0	0	1	0	0	0	24
Vermont	2	7	0	1	0	0	2	0	2	14
Virgin Islands	0	0	0	0	0	0	0	0	0	0
Virginia	5	7	2	5	1	3	0	0	1	24
Washington	9	16	6	9	8	5	3	1	1	58
West Virginia	1	2	0	2	1	1	1	0	0	8
Wisconsin	3	9	3	1	6	4	1	0	1	28
Wyoming	0	1	0	1	1	0	0	0	0	3
TOTALS	235	435	160	180	144	132	64	9	69	0