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A Study On LPG As A Fuel For Vehicles

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EXECUTIVE SUMMARY

1. The objective of this research is to provide information on the use of liquefied petroleum gas (LPG) in vehicles overseas to familiarise legislators with existing practice.

2. LPG is cleaner than petrol and diesel because it is composed of predominantly simple hydrocarbon compounds. Compared with emissions from vehicles on petrol and diesel, emissions from LPG-driven vehicles contain lower levels of hydrocarbon compounds, nitrogen oxides, sulphur oxides, air toxics, and particulates.

3. Various studies show that diesel engines are more efficient than both LPG engines and petrol engines.

4. Abundant local supply is a major factor for many territories to adopt LPG as a fuel for vehicles.

5. There is no conclusive evidence to show LPG is more dangerous or less dangerous than petrol or diesel. Human factor plays an important role in affecting the safety in using LPG.

6. While capital cost is incurred in switching to LPG, LPG-driven vehicles have a slightly lower maintenance cost than petrol-driven or diesel-driven vehicles. The running cost of LPG-driven vehicles is lower than petrol-driven and diesel-driven vehicles in many territories mainly due to lower fuel tax rate on LPG.

7. The introduction of LPG in most overseas countries was non-mandatory except in the US where federal and state fleets have to comply with the National Energy Policy Act 1992 to have certain percentage of their new vehicles to run on alternative fuels. Overseas governments have used various measures, fiscal and non-fiscal, to create an environment that encourages the use of automotive LPG.

8. Overseas governments also try to enhance safety in using LPG by introducing regulations or codes of practice to regulate the use of LPG vehicles, the design and construction of LPG fuel tanks and to restrict handling of LPG to trained personnel.

9. Successful application of LPG depends on a number of factors such as the availability of the fuel, the availability of LPG conversion kits and dedicated LPG vehicles, the availability of LPG refuelling stations, safety and competitive pricing.

A STUDY ON LPG AS A FUEL FOR VEHICLES

PART 1 --- INTRODUCTION

1. Objective

1.1 In October 1996, the Legislative Council Panel on Transport requested the Research and Library Services Division (RLS) to research on taxis using liquefied petroleum gas (LPG). The objective of this research is to provide information on the use of LPG in vehicles including taxis to familiarize legislators with overseas practices.

2. Scope

2.1 The scope of the study as defined by the Panel is as follows :

- The cities/territories where LPG is used for taxis, including for example Japan, Australia, Taiwan and possibly other areas, and the time when this was introduced;
- The restrictions which may be applicable;
- An analysis of the safety aspects and if there are difficulties in travelling on steep slopes and mountainous areas;
- The accident rates and the circumstances involved; and
- Comparison of the costs and the environmental impact considerations with other types of fuel such as petrol and diesel.

3. Methodology

3.1 The research team reviewed relevant literature and searched for information over the Internet. It also sent enquiries to ministries of transport, environment, and energy as well as research institutes and oil companies in 12 territories: Australia, Canada, Japan, the Netherlands, the United States, Mexico, Belgium, Italy, Russia, South Korea, Taiwan and Singapore. So far, six territories have responded, namely Australia, Canada, Japan, Taiwan, the Netherlands and the United States. Information has also been obtained from the Hong Kong government and local academics.

4. An Overview of Automotive LPG Markets

4.1 LPG is used as a fuel in nearly 30 territories for more than 4 million vehicles. These territories together consume about 10 million metric tonnes of automotive LPG annually. As shown in Table 1, Italy was the country with the largest number of LPG vehicles in 1994 while Japan consumed the largest volume of automotive LPG in one year.

Table 1 - Major Automotive LPG Markets in 1994

Rank	Country	Number of LPG vehicles (descending order)	Rank	Country	Consumption of automotive LPG in metric tonnes (descending order)
1	Italy	1,050,000	1	Japan	1,814,000
2	Netherlands	470,000	2	Canada	1,661,000
3	Mexico	435,000	3	South Korea	1,434,000
4	C.I.S.	350,000	4	Italy	1,202,000
5	US	350,000	5	Mexico	1,185,000
6	Australia	330,000	6	US	1,012,000
7	Japan	305,000	7	Australia	890,000
8	South Korea	278,000	8	Netherlands	810,000
9	Canada	140,000	9	C.I.S.	292,000
10	Poland	52,000	10	Thailand	140,000

Sources: World LPG Forum, 1995
BK Gas Statistics, 1995

4.2 Examples cited in the rest of the paper would be mainly the Netherlands, the US, Australia, Japan and Canada as they are those territories with large number of LPG vehicles and high consumption of automotive LPG. While the experience of Italy, C.I.S., Mexico and South Korea is also relevant, little information on them is available.

Table 2 - Number and Major Types of LPG Vehicles in Selected Territories

	Time of introduction	% of vehicles on LPG	Major types of LPG vehicles
Netherlands	1950s	8.6 (1995)	Passenger cars
US	1912	0.3 (1994)	Light duty and medium duty trucks
Australia	1950s	6.0 (1996)	Taxis
Japan	1924 (1962 for taxis)	0.5 (1995)	Taxis
Canada	1970s	1.0 (1996)	Taxis
Austria	n.a.	n.a.	Buses
Greece	n.a.	n.a.	Taxis
Spain	n.a.	n.a.	Taxis and buses
South Korea	n.a.	n.a.	Taxis, buses, and trucks

Sources: World LPG Forum
Netherlands Agency for Energy and the Environment
Ministry of International Trade and Industry, Japan
Australian Bureau of Transport and Communications Economics
California Energy Commission
Transport Canada

4.3 LPG has been used as a fuel for vehicles as early as 1912 but only at a limited scale. The fuel became more popular in the 1970s and the 1980s when territories such as the US and Canada tried to reduce their dependence on crude oil. In the 1990s, the increased demand of the fuel is driven by rising environmental concerns.

4.4 Table 2 shows that LPG is mostly used by commercial vehicles mainly due to the need to recover the capital cost incurred in switching to LPG. A high mileage vehicle such as taxi could recover the capital cost faster than a low mileage vehicle.

4.5 Although LPG is mainly used in passenger cars such as taxis, the fuel is also applicable to other types of vehicles such as vans, trucks and buses. LPG trucks are common in the US. There are LPG buses in Spain and South Korea. Most of the LPG vehicles in Vienna are also buses.

4.6 Vehicles converted to use LPG can be dual-fuel or flexi-fuel. Dual-fuel vehicles have two separate fuel systems, with only one fuel being used at a time. In contrast, flexi-fuel vehicles have one fuel system operating on a mixture of fuels. Dual fuel vehicles and flexi-fuel vehicles allow LPG to be used in parallel with other fuels. They are common in Australia, the US, the Netherlands and Canada. However, the number of these dual-fuel and flexi-fuel vehicles is not available. Details of dual-fuel and flexi-fuel vehicles are being awaited.

4.7 LPG has its advantages and disadvantages when compared to fuels like petrol and diesel. Part 2 gives a comparison of LPG with petrol and diesel in the following five aspects:

- environmental impact;
- efficiency and performance;
- availability;
- safety; and
- cost.

4.8 Part 3 discusses how overseas governments provide an environment to encourage the use of automotive LPG. Part 4 analyses the implications for Hong Kong in switching to LPG.

PART 2 --- LPG AS AN AUTOMOTIVE FUEL

5. Environmental Impact

5.1 Vehicle emission is a major source of air pollution especially in the urban area. To reduce pollution, many governments would encourage the use of cleaner alternative fuel. LPG is one of the leading alternative fuels.

5.2 LPG is cleaner than petrol and diesel because it is composed of predominantly simple hydrocarbon compounds. LPG is free of lead and most additives and contains very little sulphur. Compared with emissions from vehicles on petrol and diesel, emissions from LPG-driven vehicles contain lower levels of hydrocarbon compounds (HC), nitrogen oxides (NO_x), sulphur oxides, air toxics, and particulates (Table 3).

Table 3 - Environmental Impact of LPG, Petrol and Diesel (Relative to LPG)

	LPG	Petrol	Diesel
Regulated Exhaust Components			
CO	base	-	0
HC	base	-	0
NO_x	base	-/0	-
Particulates	base	0	-
Unregulated Exhaust Components			
NO_2	base	-	-
SO_2	base	-	-
Benzene	base	-	0
PAH	base	0	-
1,3-Butadiene	base	-	-
Formaldehyde	base	-	-
Other Impact on the Environment			
Summersmog	base	-	-
Wintersmog	base	0	-
Acidification	base	-	-
Global warming	base	-	0

Sources : Netherlands Agency for Energy and the Environment
TNO Road Research Institute
United States Environmental Protection Agency

Remarks : Regulated exhaust components are those under the regulations of Hong Kong
+ represents better than LPG
0 represents more or less equal to LPG
- represents worse than LPG

Emissions from Different Models of Vehicles

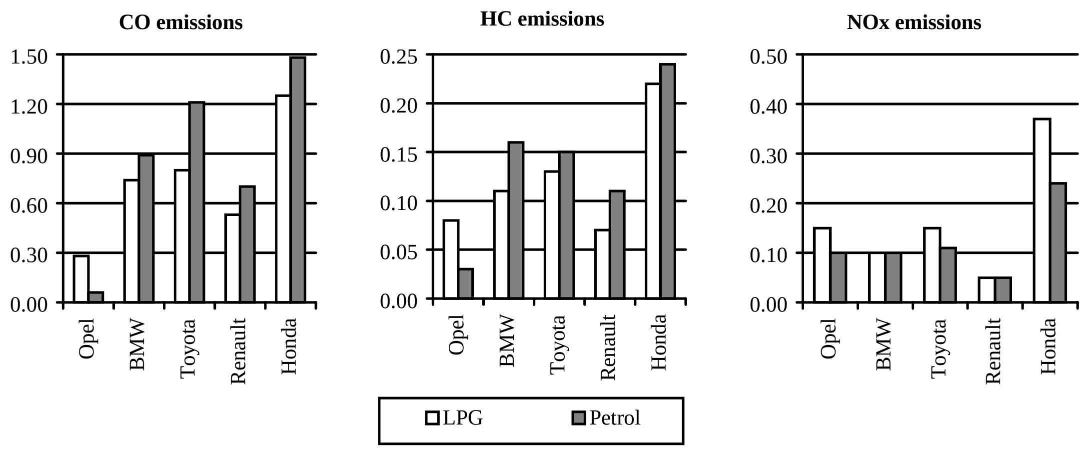
5.3 Table 4 shows research results of LPG-driven vehicles emitting less carbon monoxide (CO) and hydrocarbon compounds (HC) than petrol-driven vehicles in four models. LPG-driven vehicles emit more nitrogen oxides (NO_x) than petrol-driven vehicles in three models.

Table 4 - Emissions of Passenger Cars on LPG and Petrol (grams per km)

	CO	HC	NOx
LPG			
Opel Vectra 2.0 16V	0.28	0.08	0.15
BMW 318I	0.74	0.11	0.10
Toyota Carina E 1.6 Xli	0.80	0.13	0.15
Renault Laguna 2.0	0.53	0.07	0.05
Honda Accord 2.0 iS	1.25	0.22	0.37
Petrol			
Opel Vectra 2.0 16V	0.06	0.03	0.10
BMW 318I	0.89	0.16	0.10
Toyota Carina E 1.6 Xli	1.21	0.15	0.11
Renault Laguna 2.0	0.70	0.11	0.05
Honda Accord 2.0 iS	1.48	0.24	0.24

Source : TNO Road Research Institute

Chart 1 - Emissions of Passenger Cars on LPG and Petrol (grams per km)



Source: TNO Road Research Institute

Emissions from Vehicles Before and After Conversion

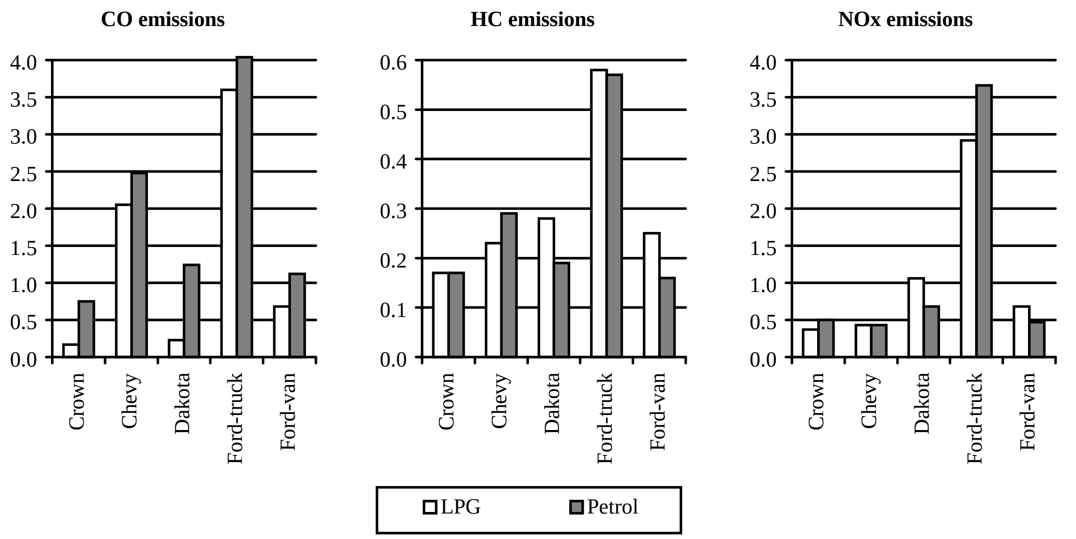
5.4 Table 5 shows that there are smaller amounts of carbon monoxide (CO) in the emissions for all the five models of vehicles after conversion from petrol-driven to LPG-driven. The amount of hydrocarbon compounds (HC) and nitrogen dioxides (NO_x) found in emissions remains more or less the same before and after the conversion.

Table 5 - Emissions of Vehicles Before and After Conversion (grams per km)

	CO	HC	NOx
LPG			
1988 Crown Victoria	0.17	0.17	0.37
1989 Chevy Pickup	2.05	0.23	0.43
1990 Dakota	0.23	0.28	1.06
1990 Ford 1-ton truck	3.60	0.58	2.92
1992 Ford van	0.68	0.25	0.68
Petrol			
1988 Crown Victoria	0.75	0.17	0.50
1989 Chevy Pickup	2.48	0.29	0.43
1990 Dakota	1.24	0.19	0.68
1990 Ford 1-ton truck	4.04	0.57	3.66
1992 Ford van	1.12	0.16	0.47

Source : United States Environmental Protection Agency

Chart 2 - Emissions of Vehicles Before and After Conversion (grams per km)



Source : United States Environmental Protection Agency

5.5 The advantage of LPG in terms of environmental impact over other fuels is getting smaller as a result of technological progress. The introduction of three-way catalytic convertors results in much lower levels of carbon monoxide (CO), hydrocarbon compounds (HC) and nitrogen oxides (NO_x) emissions from petrol-driven vehicles. The introduction of reformulated petrol and reformulated diesel also reduce the impact of the two fuels on the environment.

6. Efficiency and Performance

6.1 Efficiency of LPG is similar to that of petrol depending on the measure used. However, both LPG engines and petrol engines are not as efficient as diesel engines which have a much higher compression ratio[1]. The results of various tests are consolidated in Table 6.

Table 6 - An Indication of the Relative Efficiency and Performance of LPG, Petrol and Diesel

	LPG	Petrol	Diesel
Compression ratio	Base	-/0	+
Distance travelled on 1 kg of fuel (km)	Base	-	+
Distance travelled on 1 litre of fuel (km)	Base	+	+
Maximum power (kW/rpm)	Base	0	+
Maximum torque (kg-m/rpm)	Base	-/0	+

Sources: Japan LPG Association
Netherlands Agency for Energy and the Environment
TNO Road Research Institute
Committee for the Safety Maintenance of LPG Vehicles

Remarks : + : a range of various efficiency or performance tests results which is better than LPG
0 : a range of various efficiency or performance tests results which is more or less equal to LPG
- : a range of various efficiency or performance tests results which is worse than LPG

6.2 A diesel-driven vehicle travels a longer distance than an LPG-driven vehicle and a petrol-driven vehicle with the same mass or volume of fuel (Table 6). In terms of energy conservation, diesel is better than LPG and petrol. An LPG-driven vehicle travels longer distance than petrol with same mass of fuel but shorter distance than petrol with the same volume of fuel.

6.3 LPG engines also have a similar performance as petrol engines in terms of power output and torque. Therefore, LPG-driven vehicles should have similar performance in climbing slopes and travelling on mountainous areas as petrol-driven vehicles.

[1] Compression ratio measures the extent to which the air-fuel mixture can be compressed in the cylinder of a car engine. Usually, the higher the compression ratio, the higher is the efficiency of the engine. Diesel (unlike LPG and petrol) does not mix with air before combustion. Instead, it is injected into the cylinder at the time of ignition.

7. Availability

7.1 LPG is a by-product of petroleum and natural gas. It can be obtained from two sources, the refining of petroleum and the extraction of natural gas. LPG obtained from the refining of petroleum amounts to 10% to 15% of the quantity of petroleum while LPG obtained from the extraction of natural gas amounts to 3% of the quantity of natural gas. The availability of LPG is more limited than petrol.

7.2 A steady supply of LPG at stable price is important in encouraging consumers to switch to the fuel. Abundant local availability is a major factor for territories like the Netherlands, Australia, the US and Canada to adopt LPG as an alternative fuel for vehicles (Table 7). For example, the availability of LPG from Bass Strait was a key factor leading to rapid increase in utilisation of LPG as a fuel for vehicles in 1970s in Australia.

Table 7 - Major Source of LPG in Selected Territories

	Local supply	Import
Netherlands	✓	
US	✓	
Australia	✓	
Japan		✓
Canada	✓	

Sources: Netherlands Agency for Energy and the Environment
Ministry of International Trade and Industry, Japan
Australian Bureau of Transport and Communications Economics
California Energy Commission
Transport Canada

8. Safety

Fire and Explosion

8.1 LPG tends to be more inflammable than both petrol and diesel because it has a wider flammability limit[2].

8.2 Accidents involving LPG sometimes result in fire or in explosion. Explosion happens when there are sufficient amounts of both air and LPG and they are ignited to generate a large amount of heat and rapid air movements in a very short period of time. If heat is released gradually, the burning of the fuel tends to lead to fire rather than explosion. This means that ventilation or air movement is important in safety in storage and transport of LPG.

2 Flammability limit of a fuel is a range of percentages within which the fuel would burn in air; outside the range, the fuel would not burn. The percentage is the ratio between the volume of the fuel (in gaseous state) to the volume of air in a given area. A fuel with a wide flammability limit burns more readily than a fuel with narrow limit.

8.3 Examples of explosions involving LPG vehicles were found in Japan where two explosions happened in 1962 and another two in 1963. An explosion involving an illegally-converted LPG vehicle took place in June 1992 in Taiwan[3].

8.4 The characteristics of LPG have implications on the design of fuel tanks, storage tanks and refuelling stations. One example is Japan's requirement on LPG tanks to be fixed permanently into position after the explosions in 1962 and 1963.

Asphyxiation

8.5 LPG is dangerous when it is allowed to accumulate in enclosed areas such as garages. LPG is denser than air and tends to sink and accumulate. It evaporates quickly and expands 270 times its volume in liquid state. Sufficient quantity of LPG can cause asphyxiation due to the quick displacement of oxygen. Since LPG is colourless and odourless, a pungent smell is often added to it so that it can be easily detected in case of leakage.

8.6 This characteristic has led to the restriction over the route of LPG vehicles and their use of tunnels in some territories. Further details are in paragraphs 11.3 to 11.6.

Human Factor

8.7 There is no conclusive evidence to show that LPG is more dangerous or less dangerous than petrol or diesel. Human factor plays an important role in affecting the safety in using LPG. For example, Japan has not have any explosion or serious accidents in the past 30 years since it introduced various safety measures regulating the use of LPG.

8.8 A study in Canada showed that human error was the major cause of accidents involving LPG vehicles (Table 8). The information on 80 accidents was gathered by Transport Canada's investigation office and the Ontario Ministry of Consumer and Commercial Relations from August 1981 to May 1986.

3 LPG vehicles in Taiwan were allowed on the road officially in 1995 only.

Table 8 - Accidents Involving LPG Vehicles by Category in Canada (1981-1986)

Accident Category	Number of Cases	%
Human error	47	58
Equipment failure	13	16
Collision	10	13
Undetermined	10	13
Total	**80**	**100**

Source : Transport Canada

8.9 Accidents falling in the human error category generally involve careless fuel handling and faulty workmanship such as poor sealing of bodywork around remote refuelling connectors. Accidents happened during refuelling in 25 cases or 31% of the total number of accidents, indicating the danger inherent in that operation.

9. Cost

9.1 There are three main types of cost that consumers would consider in switching to LPG. The three types of cost are:

- capital cost;
- maintenance cost; and
- fuel cost.

<u>Capital Cost</u>

9.2 In switching to LPG, car owners can purchase LPG vehicles produced by car manufacturers commonly called original equipment manufacturers (OEMs) or convert their petrol-driven or diesel-driven vehicles into using LPG.

Table 9 - Major Form of LPG Vehicles in Selected Territories

	OEMs	Conversion
Netherlands		✓
US		✓
Australia		✓
Japan	✓	
Canada		✓

Sources : Netherlands Agency for Energy and the Environment
Ministry of International Trade and Industry, Japan
Australian Bureau of Transport and Communications Economics
California Energy Commission
Transport Canada

9.3 Table 9 shows that conversion is more common in the Netherlands, the US, Australia and Canada while dedicated LPG-driven vehicles produced by OEMs are more common in Japan. The cost of conversion varies from territories to territories (Table 10) partly due to the availability of government subsidies on conversions in some territories as shown in paragraphs 10.4 to 10.6 below. In Japan, the price of an LPG-driven vehicle is similar to a petrol-driven vehicle.

Table 10 - Cost of Conversion in Selected Territories

	US	Australia	Japan
Conversion Cost (HK$)	21,728	10,746	13,000

Sources : US Department of Energy
Information Research Services, Australian Parliament
Ministry of International Trade and Industry, Japan

Maintenance Cost

9.4 LPG-driven vehicles have a slightly lower maintenance cost than petrol-driven or diesel-driven vehicles. LPG as a gas does not wash lubricant from the cylinder walls of the engine as gasoline and diesel. This washing action is detrimental to any components that rely on the lubrication system for their proper functioning. The cleaner burning characteristics of LPG also reduce maintenance requirements and cost.

Fuel Cost

9.5 The switch to LPG involves a certain amount of initial cost but the running cost of LPG-driven vehicles can be much lower than vehicles driven by petrol or diesel in many territories depending on government policy, especially that on fuel tax.

9.6 Table 11 shows that in Japan the retail price of LPG is the cheapest. Nevertheless, the price of LPG net of tax is 0.2 yen (HK¢0.17) higher than that of petrol and slightly cheaper than that of diesel.

Table 11 - The Price and Tax of Automotive Fuel in Japan in 1995

	Price/litre (yen)	Tax/litre (yen)	Price net of tax/litre (yen)
LPG	55	9.8	45.2
Petrol	100	55	45
Diesel	80	32	48

Source : Ministry of International Trade and Industry, Japan

PART 3 --- GOVERNMENT POLICIES ON AUTOMOTIVE LPG

10. Measures in Encouraging the Use of LPG

10.1 The introduction of LPG in most overseas countries was non-mandatory. The exception is the US where federal and state fleets have to comply with the National Energy Policy Act 1992 so that certain percentage of the fleets are run on alternative fuel. All overseas governments would create an environment that encourages the use of the fuel through fiscal and non-fiscal measures. The governments also introduce various regulations to ensure the safe use of LPG.

Fiscal Measures

Fuel tax

10.2 Tax incentives can be in many forms. The most common incentive is low fuel tax rate. As indicated in Table 12, the fuel tax rate on automotive LPG is lower than both that on petrol and diesel.

Table 12 - Comparison of Fuel Tax Rates (Relative to Petrol) in 1994 (%)

	Petrol	Diesel	LPG
Italy	100	74	31
Netherlands	100	62	11*
Japan	100	60	18
Australia	100	100	nil
Greece	100	65	14
Spain	100	73	14
France	100	61	38

Source : World LPG Forum

Remark : * include additional surcharge in road tax

Sales Tax

10.3 In addition to giving excise free status to LPG, the Australian government also exempts LPG conversion equipment from sales tax.

Subsidies

10.4 Fiscal measures can also be in various forms of subsidies. The major type of subsidy is that on conversions.

10.5 The Japanese Government provides subsidy to owners of diesel-driven vehicles weighing 2.5 tonnes or less if they purchase LPG vehicles to replace their own vehicles. In case of conversion, subsidy is given for half of the modification expenses with a ceiling at 100,000 yen (HK$ 8,280) per vehicle.

10.6 The Taipei government offers to subsidise taxis on expenses involved in using LPG. The subsidy ranges from NT$20,000 to NT$50,000 (HK$5,680-HK$14,200). The target of the Taipei government is to have 100,000 taxis switched to LPG in the three-year period of 1995-1997.

Non-Fiscal Measures

10.7 Governments also encourage the use of LPG vehicles through non-fiscal measures.

Policy Affecting Refuelling Stations

10.8 The popularity of LPG as a fuel for vehicles depends very much on the availability of sufficient LPG refuelling stations at convenient locations. Clear and long term policies are required to encourage long term investment on LPG refuelling stations. The availability of refuelling stations is also affected by legislative requirements. Details of such requirements are given in paragraphs 11.7 to 11.17.

Table 13 - Number of LPG Refuelling Stations in Selected Territories

Country	Number of LPG refuelling station	Number of vehicles per station
Canada	5,000	28
US	3,300	106
Australia	2,570	128
Netherlands	2,000	235
Japan	1,921	159
Italy	1,900	553
Mexico	1,500	290
Germany	10	200
Norway	4	250
Taiwan	3	1,333

Sources : World LPG Forum
BK Gas Statistics, 1995

Measures to Reduce Pollution

10.9 In 1992, Italy has introduced a measure under which vehicles driven by petrol and diesel can only drive on alternative days while LPG vehicles are permitted to drive every day in periods of heavy pollution.

10.10 In Japan, specified vehicles such as trucks and buses with high nitrogen oxides (NO_x) emission are not allowed to be used in areas such as Tokyo and Osaka since December 1993.

10.11 The National Energy Policy Act 1992 of the US requires federal and state fleets to begin buying alternative fuel vehicles to reduce pollution. In federal fleets, alternative fuel vehicles must equal 25% of new vehicles purchase in 1996, increasing to 75% in 1999 and beyond. In state fleets, alternative fuel vehicles must make up 10% of new vehicles purchased in 1996, increasing to 75% in 2000 and beyond. The Act authorises the Department of Energy to decide whether to extend the requirements to private and municipal fleets after evaluating the ability of other measures to displace petrol for vehicles.

10.12 Nevertheless, there is no requirement to convert existing fleet vehicles. The purchase requirement applies only to replacement or new vehicle purchases. There are incentives for fleets to purchase a greater number than required, purchase earlier than required, or purchase “cleaner” vehicles than required. The incentives are in the form of credits or discounts, which can be used for later purchases. These discounts are transferable and can be sold to others.

11. Measures in Enhancing Safety in Using Automotive LPG

11.1 To enhance safety in using LPG, regulations or codes of practice are introduced to regulate the safe handling of LPG, the use of LPG vehicles, the design and construction of LPG fuel tanks as well as to impose restrictions on LPG refuelling stations and to impose requirements for regular inspection of LPG vehicles and proper training of personnel handling LPG.

Fuel System

11.2 The main purpose of the regulations governing the fuel system of LPG vehicles is to prevent leakage, minimise the possibility of accidents and reduce damage in case of accidents. The regulations mainly require :

- conversions to be done by authorised persons;
- regular inspections including a check of LPG leakage along the fuel system to be done by approved technicians;
- materials and thickness of fuel tanks to follow specifications;

- various parts of the fuel tanks to follow specifications to include devices such as liquid level indicator, overfilling prevention device, safety relief valve and emergency shut-off valve;

- LPG tanks not to fill more than 80% in the US, 80% to 85% in the Netherlands and 85% in Japan; and

- LPG vehicles to pass barrier collision and fire tests.

Route of LPG Vehicles

11.3 As mentioned in paragraph 8.5, LPG can be dangerous if it is allowed to accumulate in enclosed areas such as tunnels, enclosed car parks and enclosed garages. Overseas governments have different policy on the route of LPG vehicles.

Prohibition

11.4 LPG vehicles are not allowed to use several tunnels connecting New York City to New Jersey and they are not allowed in Boston areas in the US. However, they are allowed to travel in all other tunnels and areas in the US.

Improved Ventilation

11.5 The Netherlands requires good ventilation in enclosed workshops and car parks. Installation of gas detection device in these places is compulsory in the Netherlands.

No Restriction

11.6 There is no particular restriction concerning the routes of LPG vehicles in Japan. LPG vehicles can use all underground car parks and tunnels.

Refuelling Stations

11.7 To ensure safety at refuelling stations where a large amount of LPG is stored, various territories have imposed restrictions on the design of the stations. Japan has the most stringent requirements (Table 14).

Table 14 - Requirements on Refuelling Stations in Selected Territories

	Co-existence with other fuel stations		**Storage tank**	
	Permitted	**not permitted**	**above ground**	**underground/ in a mound**
Netherlands	✓			✓
US	✓		✓	
Australia	✓		✓	
Japan		✓		✓
Canada	✓		✓	

Sources : Netherlands Agency for Energy and the Environment
Ministry of International Trade and Industry Japan
Information and Research Services, Australian Parliament
California Energy Commission
Environment Canada

Co-Existence of Fuel Stations

11.8 The co-existence of LPG and petrol/diesel service stations is not allowed in Japan but is allowed in the Netherlands, the US, Australia and Canada.

Location of Storage Tanks

11.9 Storage tanks at the refuelling stations are allowed to be above-ground in the US, Australia and Canada. Australia considers above-ground storage tanks as safe as underground tank. The determining factors for storage tank location are space availability and the cost of excavation rather than safety.

11.10 In the Netherlands, the capacity of LPG storage tanks should not exceed $80m^3$ and such tanks are required to be in a mound or underground to reduce fire risk in recent years. Before early 1990s, above-ground storage tanks were allowed. In addition, the minimum capacity of storage tanks is $20m^3$. This aims at minimising the number of road tanker trips.

11.11 In Japan, in areas where there is a concentration of type 1 or type 2 buildings[4], the storage tanks have to be buried below ground level.

4 Type 1 buildings include schools, hospitals, clinics, theatres with more than 300 seats and historical sites. Type 2 buildings are domestic buildings.

Distance

11.12 Most territories require LPG refuelling stations to be situated away from populated areas. The minimum distance between LPG refuelling stations and buildings vary according to factors like the design of storage tanks.

11.13 The location of storage tanks affects the distance required between LPG refuelling stations and other buildings. Distance required is often reduced if the storage tanks are located underground. For example, the distance required in Japan is 16.97m to 30m from type 1 buildings and 11.31m to 20m from type 2 buildings depending on the capacity of the tanks. The distance could be reduced by 30% if the storage tanks is underground.

11.14 The installation of water sprinkler system, fire-fighting equipment and fire wall can also reduce the distance required. For example, in the US, LPG refuelling facilities must be located at 7.6m from buildings but the distance can be reduced to 3m if fire walls are installed.

11.15 In the Netherlands, a distance of at least 80m between refuelling stations (for storage tanks exceeding $20m^3$) and buildings is required for new refuelling stations. The minimum distance between existing LPG stations and buildings remains to be 20m.

11.16 In Australia, the minimum distance between LPG refuelling stations and public facility such as hospital, schools and dwellings is 15m.

Other Measures Adopted in Refuelling Stations

11.17 There are other measures governing the operation of LPG refuelling stations. The measures adopted in Japan are used for illustration. These include :

- LPG equipment must be fitted with pressure gauges, and with mechanism which can immediately bring pressure down to the acceptable level;
- appropriate measures such as the display of labels guiding the appropriate use of valves and cocks must be taken;
- equipment providing backup electricity supply for equipment necessary for ensuring safety, such as automatic control equipment, sprinklers, fire-prevention equipment, cooling water pump, emergency lighting equipment, communication equipment, must be installed;
- equipment for the detection of gas leakage and sounding of warning must be installed; and
- storage tanks and their supports must be covered with non-inflammable heat insulating material, and fitted with effective cooling facilities.

Training of Personnel Handling LPG

11.18 Proper training of personnel handling LPG is important in ensuring safety in using the fuel. Most territories require the operating staff of refuelling stations as well as repair and maintenance staff to be trained and registered.

11.19 Industry associations such as the National Automotive Gas Association of Japan, Japan LPG Association and the Australian Liquefied Petroleum Gas Association play an important role in training and monitoring the standards of personnel in handling LPG.

Safe Handling of LPG

11.20 Japan has developed a comprehensive set of rules concerning the safe handling of LPG. Strict compliance to these rules ensures safety in using LPG.

Import of LPG

11.21 The rules governing the import of LPG include:

- those who intend to import high pressure gas must submit report to the mayor of the respective province or prefecture; and
- after the gas has been imported, inspection of the characteristics of LPG and of the containers has to be conducted by the relevant mayor.

Storage of LPG

11.22 The rules to follow in terms of the storage of LPG are as follows:

- approval from the mayor of the respective prefecture or province is required (the same applies to modification works); and
- when construction or modification of LPG storage is completed, inspection has to be conducted by the relevant mayor.

Penalty for Non-compliance

11.23 Failure to comply with the above regulations will lead to a range of actions including:

- warning and order for compliance with standards;
- disclosure of the name of the company concerned;
- order for dismissal of person in charge for sales; and
- cancellation of licence.

PART 4 --- ANALYSIS

12.1 LPG has a long history as an alternative fuel for vehicles in overseas territories. Successful application of the fuel depends on a number of factors. The important ones are as follows:

- availability of the fuel;
- availability of LPG conversion kits or LPG dedicated vehicles;
- availability of refuelling stations;
- safety; and
- competitive pricing.

Availability of LPG

12.2 Abundant local supply is a main reason for overseas territories to adopt LPG as an alternative fuel. Measures have to be introduced to ensure a steady supply of LPG at relatively stable price if it is adopted as a fuel for vehicles in Hong Kong which depends on imports for the fuel.

12.3 LPG is not used as an automotive fuel in Hong Kong but is used for domestic and commercial purposes. LPG is imported from various countries such as Singapore and the Philippines. These two countries together supply more than 80% of the LPG consumed in Hong Kong in 1995.

Availability of LPG Conversion Kits or Vehicles

12.4 The introduction of LPG requires either LPG dedicated vehicles or LPG conversion kits. LPG dedicated vehicles are common in Japan while LPG conversion kits are available in such countries as the US, Canada and the Netherlands.

12.5 The prices of LPG dedicated vehicles in Japan are similar to those running on petrol. For the costs of conversion kits, details have been shown in Table 10. Apart from costs, another consideration is the availability of trained personnel in installing conversion kits.

Availability of Refuelling Stations

12.6 The availability of sufficient LPG refuelling stations affects the acceptance of the fuel by consumers. The availability of refuelling stations is affected by government requirements on the design. Whether LPG service stations are allowed to co-exist with petrol/diesel stations, whether storage tanks are allowed to be installed above-ground and the distance required between LPG refuelling stations and buildings would affect the space needed for a refuelling station and its location.

Safety

12.7 Overseas governments have introduced measures to minimise the risk in using and handling the fuel. Such measures include restrictions on the route of LPG vehicles and on the design of LPG vehicles. Proper training and registration of personnel handling LPG is also an important requirement in ensuring safety.

12.8 In Hong Kong, LPG is governed by the Gas Safety Ordinance (Cap. 51) while petrol and diesel are governed by the Dangerous Goods Ordinance (Cap. 295). Under these Ordinances, no person shall store, convey or use any dangerous goods in excess of the exempted quantity, except under licence granted by the authorities. The exempted quantity of LPG, petrol and diesel are shown in Table 15.

Table 15 - Exempted Quantity of LPG, Petrol & Diesel for Storage and Conveyance

	LPG (litre)	**Petrol (litre)**	**Diesel (litre)**
Exempted Quantity	130	20	2,500

Source : Laws of Hong Kong.

Competitive Pricing of LPG

12.9 The pricing of LPG would determine its popularity among consumers; in turn the size of the automotive LPG market would affect the willingness of investors to put money into building infrastructure such as refuelling stations. Overseas experience shows that competitive pricing of LPG is very often achieved by government policy such as that on fuel tax.

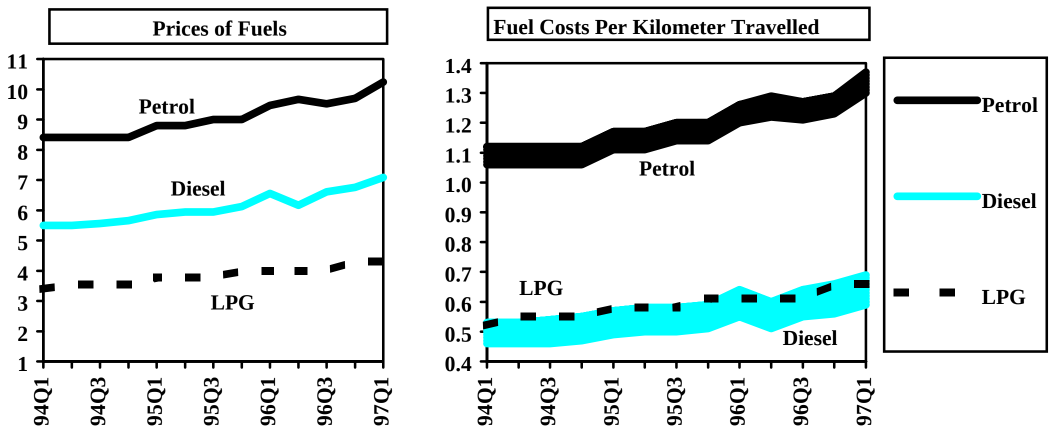
12.10 Table 16 shows the retail prices (inclusive of government duties) of LPG, petrol and diesel and the fuel cost per kilometer travelled of each fuel in Hong Kong. Prices of LPG given in Tables 16 and 17 are the prices of LPG for domestic or industrial use. LPG is not subject to government duties since it is not an automotive fuel.

12.11 The fuel costs of LPG and diesel to travel one kilometer are similar, and both are cheaper than petrol (Table 16 and Chart 3).

Table 16 - Prices of Fuels and Fuel Cost Per Kilometer Travelled : Inclusive of Government Duties (HK$)

(as at the end of)		Prices of Fuels (litre)			Fuel Cost Per Kilometer Travelled		
		LPG	Petrol	Diesel	LPG	Petrol	Diesel
1994	Q1	3.39	8.41	5.50	0.52	1.06-1.12	0.46-0.53
	Q2	3.54	8.41	5.50	0.55	1.06-1.12	0.46-0.53
	Q3	3.54	8.41	5.56	0.55	1.06-1.12	0.46-0.54
	Q4	3.54	8.41	5.66	0.55	1.06-1.12	0.47-0.55
1995	Q1	3.78	8.80	5.86	0.58	1.11-1.17	0.49-0.57
	Q2	3.78	8.80	5.94	0.58	1.11-1.17	0.50-0.58
	Q3	3.78	9.00	5.94	0.58	1.14-1.20	0.50-0.58
	Q4	3.99	9.00	6.12	0.61	1.14-1.20	0.51-0.59
1996	Q1	3.99	9.47	6.56	0.61	1.20-1.26	0.55-0.64
	Q2	3.99	9.67	6.16	0.61	1.22-1.29	0.51-0.60
	Q3	3.99	9.52	6.61	0.61	1.21-1.27	0.55-0.64
	Q4	4.31	9.70	6.76	0.66	1.23-1.29	0.56-0.66
1997	Q1	4.31	10.24	7.08	0.66	1.30-1.37	0.59-0.69

Chart 3 - Prices of Fuels and Fuel Cost Per Kilometer Travelled : Inclusive of Government Duties (HK$)



Sources : Census and Statistics Department
Shell Company

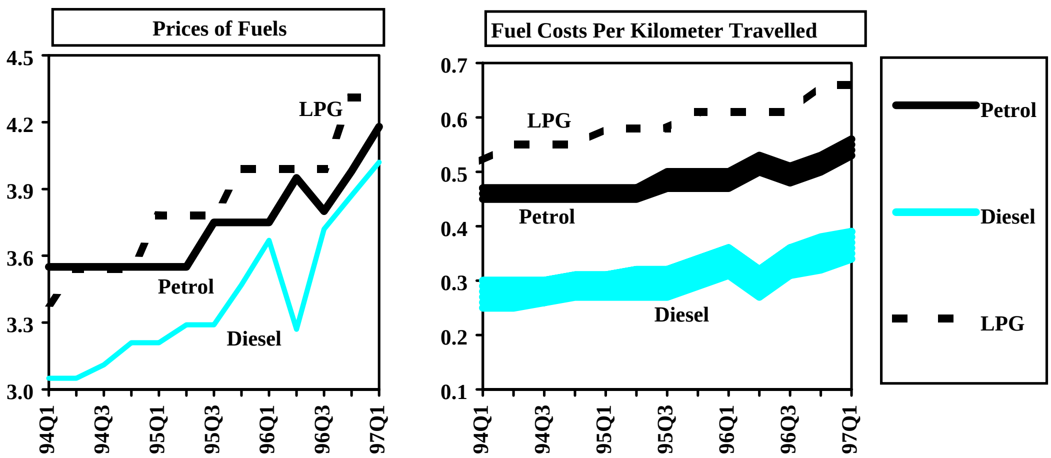
Remarks:
1. Price of LPG per litre is calculated by converting from mass (kg) to volume (litre).
2. Price of LPG is not subject to government duties as it is not an automotive fuel.
3. The calculation of the fuel cost per kilometer is based on data supplied by Toyota Motor Corporation that 1 litre of LPG, petrol and diesel travels 6.5km, 7.5-7.9km and 10.3-12.0km respectively.

12.12 Table 17 shows the comparison on fuel costs exclusive of government duties. Having excluded government duties, fuel cost per kilometer of LPG is the highest, around 14-20% higher than that of petrol and about 65-90% higher than that of diesel (Table 17 and Chart 4).

Table 17 - Prices of Fuels and Fuel Costs Per Kilometer Travelled : Exclusive of Government Duties (HK$)

(as at the end of)		Prices of Fuels (litre)			Fuel Cost Per Kilometer Travelled		
		LPG	Petrol	Diesel	LPG	Petrol	Diesel
1994	Q1	3.39	3.55	3.05	0.52	0.45-0.47	0.25-0.30
	Q2	3.54	3.55	3.05	0.55	0.45-0.47	0.25-0.30
	Q3	3.54	3.55	3.11	0.55	0.45-0.47	0.26-0.30
	Q4	3.54	3.55	3.21	0.55	0.45-0.47	0.27-0.31
1995	Q1	3.78	3.55	3.21	0.58	0.45-0.47	0.27-0.31
	Q2	3.78	3.55	3.29	0.58	0.45-0.47	0.27-0.32
	Q3	3.78	3.75	3.29	0.58	0.47-0.50	0.27-0.32
	Q4	3.99	3.75	3.47	0.61	0.47-0.50	0.29-0.34
1996	Q1	3.99	3.75	3.67	0.61	0.47-0.50	0.31-0.36
	Q2	3.99	3.95	3.27	0.61	0.50-0.53	0.27-0.32
	Q3	3.99	3.80	3.72	0.61	0.48-0.51	0.31-0.36
	Q4	4.31	3.98	3.87	0.66	0.50-0.53	0.32-0.38
1997	Q1	4.31	4.18	4.02	0.66	0.53-0.56	0.34-0.39

Chart 4 - Prices of Fuels and Fuel Costs Per Kilometer Travelled : Exclusive of Government Duties (HK$)



Sources : Census and Statistics Department
Shell Company

Remarks:
1. Price of LPG per litre is calculated by converting from mass (kg) to volume (litre).
2. Price of LPG is not subject to government duties as it is not an automotive fuel.
3. The calculation of the fuel cost per kilometer is based on data supplied by Toyota Motor Corporation that 1 litre of LPG, petrol and diesel travels 6.5km, 7.5-7.9km and 10.3-12.0km respectively.

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