INTRODUCING NATURAL GAS / LIQUEFIED PETROLEUM GAS BUSES AND HEAVY DUTY VEHICLES IN HONG KONG -

FEASIBILITY STUDY

EXECUTIVE SUMMARY

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1 INTRODUCTION

The objectives of this study are to assess the technical feasibility of introducing natural gas (NG) or liquefied petroleum gas (LPG) buses and heavy duty vehicles to Hong Kong with a view to improving air quality.

In the context of this study, the term NG includes both compressed natural gas (CNG) and liquefied natural gas (LNG); buses include both public and private buses; and heavy duty vehicles (HDVs) includes both medium goods vehicles (MGVs) and heavy goods vehicles (HGVs).

The study was divided into 7 tasks and these are summarised in the following sections.

2 TASK 1 - AVAILABILITY OF NG / LPG SUPPLY

The quantity of NG or LPG fuel required to replace the diesel consumed by all buses and HDVs was estimated to be about 1.1 million tonnes per year. This includes allowances for the lower fuel efficiency expected for NG/LPG engines. For comparisons, the LPG consumed in 2006 for taxis, light buses and domestic use amounted to 430,000 tonnes. The electricity companies and Towngas are large consumers of NG and consumed 2.4 million tonnes in 2006.

Various supply options were considered for supplying the required fuel, taking into account the existing and planned infrastructure in Hong Kong and southern mainland China.

The favoured option for NG supply is to use LNG road tankers from LNG terminals in the Mainland or Hong Kong. LNG distribution by road tankers is more practical than CNG trailers, particularly for use on a large scale. Another significant advantage is the flexibility to use the fuel directly in LNG vehicles or vaporise it at the filling station for use in CNG vehicles. Such a filling station is termed a LCNG filling station.

For critical applications such as public transport, a storage depot within Hong Kong may need to be established on security of supply considerations, at least to cover supply disruptions during typhoons.

For LPG, buses and HDVs need a different grade of fuel (of much higher propane content) to that currently used by taxis and light buses. The existing LPG terminal facilities on Tsing Yi Island therefore cannot be used directly and in any case, the Tsing Yi terminals are already operating near full capacity. The only possible LPG supply option in the short to medium term is to use LPG road tankers from LPG terminals in the Mainland and distribute directly to filling stations. In general, there is currently a plentiful supply of LPG in southern mainland China.

3 TASK 2 - AVAILABILITY OF VEHICLES

International experience with gas fuelled vehicles is growing steadily. There are now over 150,000 NG/LPG buses in the world and over 120,000 gas fuelled trucks. The majority of these are CNG vehicles. Although LPG is the third most common vehicle fuel after petrol and diesel, it is relatively rarely used in heavy duty applications; there are less than about 1,000 heavy duty LPG buses and trucks worldwide. Comparing with CNG, LNG is relatively less mature with less than 2,000 vehicles of all types worldwide.

The availability of different types of vehicles are summarised in *Table 3.1*. Since coachbuilders often combine a chassis with an engine from various suppliers and build a body to suit customer requirements, the availability of engines was also considered when establishing the availability of different vehicle types.

Table 3.1 Summary of Vehicle Availability

	CNG	**LNG**	**LPG**
Single-decker buses	OEM buses available.	Few OEM buses available. Engines available.	Few OEM buses available.
Double-decker buses	Only in China. No engines of required power for use in Hong Kong.	No experience to date. Few dual-fuel engines available.	No
MGV rigid trucks	OEM available.	Non-OEM experience Engines available.	< 7 te OEM
MGV tractors	Non-OEM experience Engines available	Few OEM vehicles available. Engines available.	No
HGV	Non-OEM experience. Several engines available	Non-OEM experience. Few LNG & dual-fuel engines available.	No

It can be seen that for many of the vehicle categories, sourcing vehicles will be a challenge and even if vehicles can be sourced, there will be very few choices of vehicle models.

4 TASK 3 - ENVIRONMENTAL BENEFITS

The gap between gas engines and diesel engines has narrowed in recent years in terms of tailpipe emissions. While gas engines are fundamentally cleaner in respect of some pollutants, most notably particulates (RSP) and nitrogen oxides (NO_X), they are worse in terms of other pollutants such as hydrocarbons (HC). Gas engines also have a lower fuel economy. Simple catalytic after-treatment, however, is sufficient to bring emissions of all pollutants from a gas engine to low values meeting the latest emission standards. Diesel engines require more after-treatment to control NO_X and

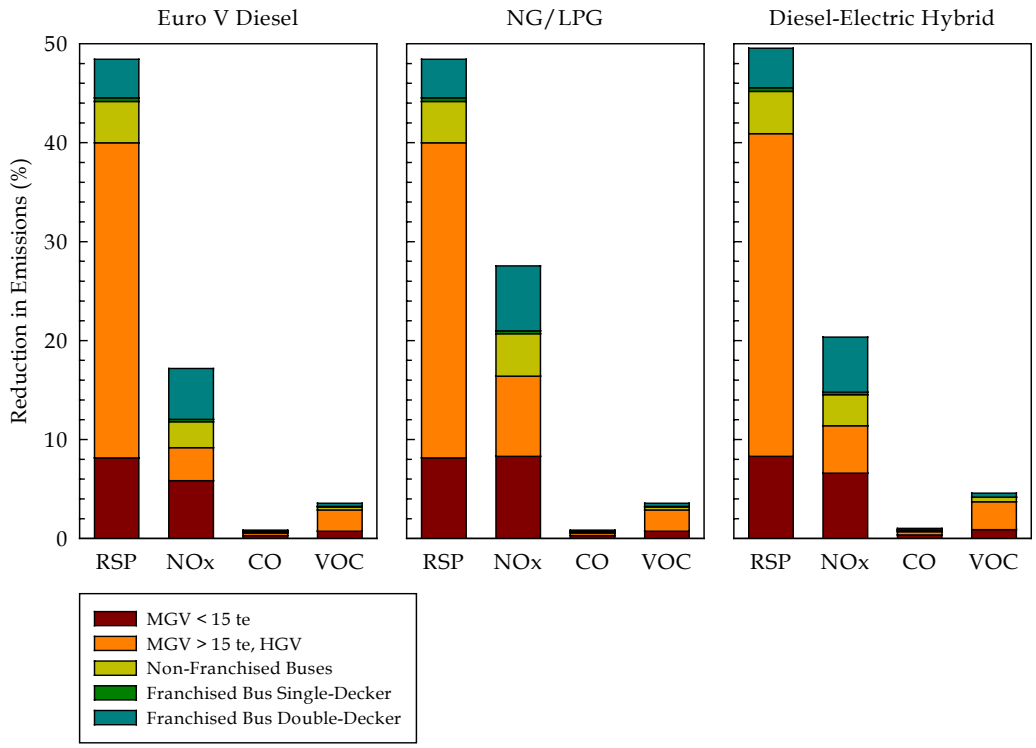
particulate emissions, but the best diesel engines available today can match the best gas engines in terms of emissions of RSP, carbon monoxide (CO) and HC. For NO_X emissions, the emission benefits offered by NG/LPG engines are diminishing as diesels improve to meet ever stricter emissions standards.

The existing bus and HDV fleet in Hong Kong (*Table 4.1*) shows that there are still a large number of pre-Euro vehicles on the road. Fleet calculations performed using EPD's EMFAC model show that significant reductions in emissions could be achieved by replacing the current diesel buses and HDVs with modern gas vehicles, especially for particulates (RSP) and NO_X. However, nearly identical reductions could be achieved by replacement with Euro V diesels which are now available. Gas engines offer some advantage only in terms of NO_X (*Figure 4.1*).

Table 4.1 ***Existing Vehicle Fleet by Euro Standard (Sep 2006)***

Vehicle	Total Licensed Vehicle	Pre-Euro (%)	Euro I (%)	Euro II (%)	Euro III (%)	Euro IV (%)
MGV / HGV	45,190	40.62	11.07	24.29	24.03	0.00
Franchised bus	5,854	11.81	23.13	45.98	19.05	0.03
Non-franchised / private bus	7,394	11.56	15.90	33.13	39.41	0.00
All buses and HDVs	58,438	33.73	12.98	27.74	25.55	0.00

Figure 4.1 ***Percent Reduction in Total Vehicle Emissions by Replacing Existing Diesel Vehicles with Euro V Diesel or Gas Vehicles***



5 *TASK 4 - RISKS FROM NG/LPG VEHICLES*

The risks of NG/LPG buses and HDVs were compared to their diesel counterparts. The analysis demonstrated that the majority of vehicle risks are associated with impact fatalities from traffic accidents. Fatalities from fuel fires contribute only a small fraction to the fatalities.

Overall, the risks of NG/LPG buses and HDVs are slightly higher than those of diesel ones, but the differences are not considered significant. Provided that any vehicle adopted in Hong Kong meet international standards, no constraints on their use are required.

Task 4 also investigated the effects of vapour cloud explosions in tunnels. Structural damage is expected to occur if the flammable mass of a released vapour cloud exceeds 100kg. Since all buses and HDVs require onboard fuel storage exceeding 100kg, it is recommended that multiple fuel tank configurations be used with each tank limited to 100kg. Each tank should also be fitted with excess flow valves to isolate any leak from the interconnecting fuel lines.

6 *TASK 5 - INFRASTRUCTURE RISKS*

The bulk transport QRA considered a range of fuel supply options. The risks are similar to the current level of risk in Hong Kong for LPG transport. No constraints are therefore required, based on bulk transport considerations.

The acceptability of risks from fixed installations such as LNG storage depots and filling stations essentially depends on ensuring sufficient plot size and separation between the facility and surrounding population. An analysis for an assumed representative LNG storage depot site near the boundary with the Mainland found the risks to be acceptable.

For filling stations, a QRA was conducted for representative LNG/LCNG, CNG and LPG configurations. It recommended:

- Underground storage is used for LNG/LCNG and LPG filling stations;
- A separation distance of 55m is required for LNG/LCNG and LPG filling stations for single-decker franchised buses, non-franchised buses, and medium and heavy goods vehicles, with underground storage limited to 25 te.
- The separation distance increases to 100m for a large bus depot supplying 1000 double-decker buses per day. Such a depot would be classified as a Potentially Hazardous Installation (PHI) on the bases of the required onsite LNG storage and would require a consultation zone of about 300m for land use planning and control within the vicinity of the facility.

The land requirement for filling stations, including separation distances, places significant constraints on the feasibility of adopting NG/LPG, particularly on a large scale. Finding suitable sites for an extensive network of filling stations is not viable in Hong Kong.

7 *TASK 6 - MAINTENANCE REQUIREMENTS*

A review of overseas experience suggests that gas vehicles have now matured and the maintenance requirements are in line with diesel vehicles. The use of NG/LPG buses and HDVs is not expected to have any impact on the resources required in terms of workshops and technicians. Workshops can be refitted to install gas detectors, upgrade ventilation etc. to meet international standards for handling NG/LPG vehicles. Franchised bus companies would maintain vehicles at their existing workshops. Non-franchised buses and HDVs would be serviced at regular maintenance workshops, a number of which would need to be refitted for handling NG/LPG vehicles. A few new purpose built workshops dedicated to NG/LPG vehicles may be required depending on the implementation scenario.

Similarly, no increase in vehicle mechanics is envisaged, although mechanics would need to undergo retraining. Training courses may be patterned on existing courses offered by the Vocational Training Council for LPG vehicles and from overseas courses for LNG, CNG and LPG.

No major constraints are envisaged in terms of maintenance requirements.

8 *TASK 7 - RECOMMENDATION FOR MOST PRACTICABLE SCENARIO*

The main findings from earlier tasks are combined in *Table 8.1* to give an overall technical feasibility for each category of vehicle. In comparison, the relatively more technically feasible category of vehicles is the CNG single-decker franchised buses. However, introducing these vehicles into Hong Kong would require a number of issues to be tackled. Establishment of the refuelling infrastructure is a key issue. The filling facilities have to be located in close vicinity to the existing bus depots to meet the operational needs of the buses. It should be noted that many of the existing bus depots are situated in dense urban areas so that finding nearby plots of land for the refuelling facilities would be difficult and are always subject to other competing land uses. Moreover, a LNG storage depot would need to be established within Hong Kong on security of supply considerations, to cater for any supply interruptions during typhoons. On the other hand, the environmental benefits that could be obtained by the use of these vehicles are increasingly insignificant in the face of advancements in diesel engine emissions control. Therefore, although CNG single-decker franchised buses are comparatively more technically feasible, their use in Hong Kong is considered not practicable with respect to their diesel counterparts.

Greater environmental benefit would be achieved by replacement of the MGV fleet. This is not viable, however, given the land requirements for LCNG filling stations and the limited number of vehicle models available. Replacement of MGVs by the latest diesel vehicles appears to be the only practicable option.

Table 8.1 Most Practical Implementation Scenarios of NG/LPG Buses and HDVs

Vehicle Type	Main Constraints	Filling Stations	Technical Feasibility[a]	Emissions Benefit over Existing Fleet[e]	Emission Benefit over Euro V Diesel[e]
Single-decker franchised buses					
CNG	Land constraints	8 stations[d], 55m separation, 600m^2	Medium[f]	Very small, 0.4% RSP, 0.3% NO_X	Negligible, 0.06% NO_X
LNG	Land constraints, vehicle availability	8 stations[d], 55m separation, 600m^2	Low	Very small, 0.4% RSP, 0.3% NO_X	Negligible, 0.06% NO_X
LPG	Land constraints, vehicle availability	8 stations[d], 55m separation, 600m^2	Low	Very small, 0.4% RSP, 0.3% NO_X	Negligible, 0.06% NO_X
Double-decker franchised buses					
CNG	No vehicles, land constraints, storage depot required	13 stations[d], 300m CZ[c], 4,000m^2	Not viable	Small, 3.9% RSP, 6.6% NO_X	Small, 1.4% NO_X
LNG	No vehicles, land constraints, storage depot required	13 stations[d], 300m CZ[c], 4,000m^2	Not viable	Small, 3.9% RSP, 6.6% NO_X	Small, 1.4% NO_X
LPG	No vehicles or engines	-	Not possible	-	-
Non-franchised buses					
CNG	Land for filling stations, facilities in Mainland	13 stations, 55m separation, 1,500m^2	Low	Small, 4.1% RSP, 4.2% NO_X	Small, 1.8% NO_X
LNG	Vehicle availability, land constraints, facilities in Mainland	13 stations, 55m separation, 1,500m^2	Very low	Small, 4.1% RSP, 4.2% NO_X	Small, 1.8% NO_X
LPG	Vehicle availability, land constraints, facilities in Mainland	13 stations, 55m separation, 1,500m^2	Very low	Small, 4.1% RSP, 4.2% NO_X	Small, 1.8% NO_X
MGV					
CNG	Land for filling stations, facilities in Mainland	58 stations, 55m separation, 1,500m^2	Not viable	Large, 36.1% RSP, 14.8% NO_X	Small, 6.6% NO_X
LNG	Land for filling stations, vehicle availability, facilities in Mainland	58 stations, 55m separation, 1,500m^2	Not viable	Large, 36.1% RSP, 14.8% NO_X	Small, 6.6% NO_X
LPG	Vehicles limited to <7 te	-	Not possible	-	-
HGV					
CNG	Vehicle availability, land for filling stations, facilities in Mainland	10 stations[b], 55m separation, 1,500m^2	Very low	Small, 3.9% RSP 1.6% NO_X	Very small, 0.7% NO_X
LNG	Vehicle availability, land for filling stations, facilities in Mainland	10 stations[b], 55m separation, 1,500m^2	Very low	Small, 3.9% RSP 1.6% NO_X	Very small, 0.7% NO_X
LPG	No vehicles or engines.	-	Not possible	-	-

a The technical feasibility is ranked as 'High', 'Medium', 'Low', 'Very low', 'Not viable' or 'Not possible' by consideration of the findings from earlier tasks of the study. The availability of vehicles/engines and the land requirements for filling stations and other infrastructure are the main constraints contributing to this ranking.

b Although 6 stations are estimated to be required based on fuel storage and number of fuelling nozzles, in practice at least 10 stations would be necessary to provide reasonable coverage around the territory.

c CZ denotes consultation zone

d The filling stations for franchised buses would need to be located in the vicinity of existing bus depots for operational needs

e The percentage reductions in emissions quoted are relative to the total vehicle fleet, including cars and light goods vehicles

f Although ranked as medium feasibility, there would still be significant obstacles to overcome with negligible environmental benefits, hence it is still considered not practicable

9 *CONCLUSIONS*

This study concluded that the introduction of LPG/NG buses and heavy duty vehicles is not practicable for reducing vehicle emissions and improving air quality in Hong Kong.

The main reasons are as follows:

Environmental Benefits

- The gap between gas engines and diesel engines has narrowed in recent years in terms of tailpipe emissions. The best diesel engines available today can match the best gas engines in terms of most pollutants except nitrogen oxides. Environmental benefits are diminishing as diesels improve to meet ever stricter emissions standards.

New fuel infrastructure

- New infrastructure would be required such as an LNG storage depot to ensure security of supply during typhoons. Risk considerations dictate that adequate separation distances are maintained between LPG/NG facilities and the surrounding population. A separation distance of 55m is required for an LNG/LPG filling station with underground storage of 25 te. For large scale implementation scenario, i.e. medium goods vehicles, about 58 stations are required. This places a great demand on land allocation for setting up the refilling infrastructure which cannot be met.

- Even for small scale implementation scenarios, there would be great difficulty in locating suitable and adequate numbers of filling stations.

Vehicle supply

- Availability of NG/LPG vehicles is expected to be a problem for many vehicle categories. Sourcing vehicles will be a challenge and even if vehicles can be sourced, there will be very few choices of vehicle models.

This study concludes that LPG/NG vehicles are not practicable for buses or heavy duty vehicles in Hong Kong because of the difficulties associated with developing the infrastructure for an entirely new fuel. Also, the resulting environmental benefits in reducing vehicle emissions and improving air quality are diminishing.