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For discussion on
22 May 2017

LEGISLATIVE COUNCIL
PANEL ON ENVIRONMENTAL AFFAIRS

Improvement of Roadside Air Quality

PURPOSE

This paper informs Members of the latest progress of improving roadside air quality.

ROADSIDE AIR QUALITY TREND

2. Vehicle tailpipe emissions are the key roadside air pollution source. The percentage contribution of vehicle fleet to the total key air pollutant emissions in Hong Kong in 2015 is in **Annex A**. In Hong Kong, buildings flanking both sides of thoroughfares could easily trap vehicle emissions, making it difficult to clean up roadside air pollution. In recent years, we have stepped up efforts to reduce vehicle emissions, which have led to discernible improvement in roadside air quality.

3. Key roadside air pollutants are respirable suspended particulates (RSP), fine suspended particulates (FSP), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). From 2012 to 2016, their roadside concentrations have decreased by 28%, 28%, 31% and 30% respectively. The concentrations are in **Annex B**.

STRENGTHENED VEHICLE EMISSION CONTROL

4. Owing to intensive use, commercial vehicles and franchised buses account for about 95% of the RSP and NOx emissions of the local vehicle fleet. While liquefied petroleum gas (LPG) or petrol taxis and light buses virtually do not emit particulates, their NOx emissions, in the absence of proper vehicle maintenance, could increase by 10 times. To improve roadside air quality, we have thus strengthened our control efforts on pre-Euro IV diesel commercial vehicles, franchised buses and gross emitters among LPG and petrol vehicles. The progress of the relevant programmes is reported in the ensuing paragraphs.

Phasing out pre-Euro IV Diesel Commercial Vehicles

5. In 2013, pre-Euro IV diesel commercial vehicles accounted for more than 85% and 70% of the RSP and NOx emissions respectively of the diesel commercial vehicle fleet. We thus launched in March 2014 an incentive-cum-regulatory scheme to progressively phase them out before 2020 with $11.4 billion set aside as ex-gratia allowance to help the affected vehicle owners. The number of these vehicles stood at about 82 000 at the time and they included goods vehicles, light buses and non-franchised buses. To bring early relief to roadside air pollution, the more polluting ones are required to be retired sooner. The application deadlines for the ex-gratia payment for various categories of DCVs, after which the licences of the concerned DCVs will not be renewed, are as follows –

Emission Design Standard of DCVs	Application deadlines
Pre-Euro	December 31, 2015
Euro I	December 31, 2016
Euro II	December 31, 2017
Euro III	December 31, 2019

To facilitate timely replacement of DCVs in the long run, we have also introduced a statutory cap of 15 years on the service life of DCVs that are first-registered on or after 1 February 2014.

6. The response to the scheme has been very encouraging. As at 30 April 2017, about 52 300 DCVs (about 64% of the eligible vehicles) were scrapped with an approved ex-gratia payment amounting to about $6.98 billion. Detailed information of DCVs scrapped under the scheme is in **Annex C**.

Retrofitting Euro II and III Franchised Buses with Selective Catalytic Reduction Devices

7. Under the franchises, franchised bus companies (FBCs) shall replace their buses before the vehicles reach 18 years-old. As it is, all pre-Euro and Euro I buses have already been retired. The Euro II and III buses will be completely phased out by 2019 and 2026 respectively. To reduce their emissions before their retirement, the Government has been offering full subsidy to the FBCs that are operating bus routes in the urban areas to retrofit some 1 030 Euro II and III franchised buses[1] with selective catalytic reduction

[1] FBCs have retrofitted their Euro II and III buses with diesel particulate filters to reduce their

devices (SCRs) to upgrade their emission performance to that of Euro IV or above level. To identify SCRs of the right design for the bus models selected for the retrofit, the FBCs completed a pre-qualification trial before commencing the large-scale retrofit. As at March 2017, 268 Euro II and 95 Euro III franchised buses were retrofitted with SCR while the rest will be retrofitted by the end of 2017.

Franchised Bus Low Emission Zones

8. Franchised buses account for up to 40% of the traffic at busy corridors in Central, Causeway Bay and Mong Kok. Requiring FCBs to use less polluting buses in such busy corridors will improve their roadside air quality. The Government has thus set up since 31 December 2015 franchised bus low emission zones (the zones) in these three districts and FBCs could only deploy low emission buses (i.e. buses meeting Euro IV or higher emission standards or Euro II and III buses retrofitted with SCRs and diesel particulate filters) to enter these zones. As a result, virtually all (i.e. over 99%) franchised buses passing through the zones are low emission buses[2] except in the first three months when the FBCs did not have sufficient low emission buses for deployment to the bus routes cutting through the zones. In the next few years, more low emission buses will join the franchised bus fleet owing to the progressive replacement of old buses with new ones that are more environmentally friendly. We expect the deployment of non-low emission buses under exceptional incidents in the future will be further reduced. We will continue to closely monitor the deployment of low emission franchised buses in the zones.

Strengthened Emission Control of LPG and Petrol Vehicles

9. Poorly maintained petrol and LPG vehicles could emit carbon monoxide, hydrocarbons and NOx up to ten times their normal levels. The hydrocarbons and NOx are key contributors to roadside air pollution. With the support of the Panel and subsequent approval from the Finance Committee, the Government introduced a new programme of $80 million for some 17 000

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particulate emissions.

[2] In incidents such as serious traffic congestion, vehicle breakdowns and traffic accidents, etc., the FBCs may need to deploy non-low emission buses to run in the zones to maintain normal bus services. During the period of April 2016 to March 2017, these incidents accounted for less than 0.8% of the total bus trips through the zones in a month. Their occurrence will be reduced when more low emission buses join their franchised bus fleets in the next few years.

LPG and petrol taxis and light buses to replace their worn-out catalytic converters and oxygen sensors; and then launched in September 2014 a strengthened emission control programme for these two types of vehicles. The programme uses portable roadside remote sensing equipment to screen out gross emitters in the petrol and LPG vehicle fleet for their owners to fix the excessive emission problem. The identified vehicles will have to pass an emission test done with the aid of a chassis dynamometer within 12 working days from receipt of an Emission Testing Notices (ETNs) of the Environmental Protection Department (EPD) or else their vehicle licences will be cancelled.

10. The programme has been very effective in tackling the excessive emission problems of petrol and LPG vehicles. As at 30 April 2017, it had screened some 1.6 million petrol and LPG vehicles and issued about 8 200 ETNs to demand those vehicles with excessive emission problem to rectify the problem and pass the dynamometer emission test within the prescribed time period. About 360 vehicles had their licences cancelled by TD for failing to fulfil the dynamometer emission test requirement. Besides, gross emitters in the petrol vehicle fleet have been reduced from about 10% to 5% and those in LPG vehicle fleet from about 80% to 20% between 2014 and 2016.

11. To further reduce gross emitters in the petrol and LPG fleets, we have carefully explored with the Transport Department (TD) the feasibility of incorporating the dynamometer emission test into its roadworthiness examination for renewal of vehicle licence. We concluded that it is more cost effective and less disruptive to vehicle owners if we target directly gross emitters by deploying more roadside remote sensors than including the dynamometer emission test in TD's roadworthiness examination since evidence so far suggested that gross emitters only make up only a small part of the petrol and LPG vehicle fleets[3]. If we are to add the dynamometer emission test into TD's roadworthiness examination, the fee could be increased by up to 106%[4] affecting all petrol and LPG vehicles. Under the current targeted approach, only those owners whose vehicles were found to have excessive emissions will be subject to payment of the test fee.

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3 The percentages of gross emitters in the petrol and LPG fleets are about 5% and 20% respectively.

4 The fees for annual roadworthiness examinations are $585 for private cars and taxis; and $695 for light buses. If the fee for the dynamometer emission test of $620 under the strengthened emission control programme for petrol and LPG vehicles is added to the annual roadworthiness examinations, the total fee will be increased to $1,205 (i.e. 106% more) for private cars and taxis and $1,315 (i.e. 89% more) for light buses.

12. We therefore are taking steps to increase the deployment of roadside remote sensors from the current three locations to five locations during workdays starting from 2018, when the additional equipment and sensor should become available. We have also informed TD's Designated Car Testing Centre operators that the Government's decision not to incorporate the dynamometer emission test into the roadworthiness examination of petrol and LPG vehicles.

Green transport technologies for Commercial Vehicles

13. We also promote the use of green transport technologies for commercial vehicles. Apart from extending the first registration tax waiver to the end of March 2018 for electric commercial vehicles, we are managing a Pilot Green Transport Fund, which encourages trials of green innovative transport technologies, and are subsidising the FBCs to test out hybrid and electric buses.

Pilot Green Transport Fund

14. The Government set up the $300 million Pilot Green Transport Fund (the Fund) in March 2011 to encourage the public transport sectors, goods vehicle operators and non-profit making organisations to test out green innovative transport technologies. Recipients of the Fund will have to record the trial data for evaluating the performance of the transport technologies concerned and to share with their peers the trial experiences so as to promote a wider use of successful technologies.

15. As at the end of March 2017, the Fund approved 94 trials with a total subsidy of about $86 million, involving electric vehicles (EVs) (including electric buses, goods vehicles, light buses and taxis), hybrid vehicles (including hybrid light buses and goods vehicles), solar air-conditioning system for coaches, electric inverter air conditioning system for coaches, and retrofitting a ferry with a diesel-electric propulsion system and an exhaust gas scrubber. A total of 44 trials have been completed for 32 electric vans, six electric buses, three electric taxis, and 28 hybrid goods vehicles, four hybrid light buses and one solar air-conditioning system for coach. 34 trial reports (including 27 interim reports) have been uploaded to the dedicated website of the Fund for public information. Results of these trial reports are summarised in paragraphs 16 – 18 below.

Electric Vehicles

16. High production cost, limited service life, long charging time and low energy density of EV batteries are the key constraints for EVs to take up commercial transportation duties. As a result, the driving ranges of EV now on the market are too short to sustain the normal operation of taxis, light buses and coaches. All the electric taxis that were once trialed under the Fund have been re-registered as private cars because a taxi under normal operation cannot spare about four hours a day for charging. Electric light buses and coaches have also experienced similar problems. The electric light bus models trialed under the Fund, after a full charge taking about two hours, could only sustain a driving range of 180 km, lower than the daily mileage of a typical public light bus. In the case of the electric single-deck coaches under trial, the driving range varies from 200 km to 280 km after a full charge, which takes as long as four hours.

17. In comparison, electric vehicles are more likely to be practicable for light goods vehicles (LGV) because they generally do not operate round the clock and undertake duties of various intensities. Trial experience found that electric LGVs might not be suitable for the logistic/courier businesses as they might incur high mileage and heavy payload. However, electric LGVs could work for operators, such as schools/universities and non-profit making organisations, which might have relatively lower daily mileage and payload. Furthermore, their relatively low mileage or short operation time could allow top-up charging as necessary. Hence, we will step up our efforts to promote the trials of electric LGVs under the Fund, particularly for those who do not need to use their LGV intensively.

18. For those commercial EVs whose performance could meet the operation modes of vehicle operators, they could save 41% to 91% of their energy cost on an individual vehicle basis as compared with their conventional counterparts.

Hybrid Vehicles

19. Higher fuel economy is the major merit of hybrid vehicles over their conventional counterparts, thereby reducing carbon emission and fuel cost. However, the actual fuel economy of a hybrid vehicle depends on the dominant driving mode of its route. A route requiring frequent start-stop will harness

better the hybrid drive-train. If a route is dominated by highway driving, a hybrid vehicle can hardly outperform its conventional counterpart in terms of fuel economy. For this reason, the trial has found that the hybrid goods vehicles' fuel saving performance ranged from negligible to 39% over their conventional counterparts whilst that of the hybrid light buses was only at 4% or below. The latter also suffered inadequate cooling for their batteries, which would compromise fuel economy performance.

Other Technologies

20. The trial of a solar air-conditioning system for coach was also completed with the result indicating a 10% fuel cost saving.

Post-trial Survey

21. In January 2017, we did a survey of the participants of the 40 trials completed by then under the Fund. They included 21 electric LGV operators, two electric coach operators, three electric taxi operators, 11 hybrid goods vehicle operators, two hybrid light bus operators and one using a solar air-conditioning system for its coach on the post-trial operation status of the vehicles/products. The survey results are summarised below –

(a) Electric LGVs: Among the 21 trial participants, only one no longer uses its trialed vehicle owing to the battery problem. The remaining participants are still using their trialed vehicles. Three of them have procured additional electric LGVs while another ten will consider procuring electric LGV in future.

(b) Electric buses (single-deck) : The two trial participants are still using the trialed vehicles, but have no plan to procure additional electric buses for the time being;

(c) Electric taxis: All electric taxis trialed under the Fund have been re-registered as private cars because they could not spare about four hours a day for charging. The three trial participants are still using the trialed vehicles as private cars. One participant has separately procured an additional electric taxi of a new model.

(d) Hybrid light/medium goods vehicles: Eight and three trial participants of hybrid LGVs and hybrid medium goods vehicles (MGVs) are still using the trialed vehicles. One of them has procured an additional hybrid LGV while another five would consider procuring hybrid LGVs in future. The three trial participants of hybrid MGVs have no plan to procure additional MGVs.

(e) Hybrid light buses: One of the two trial participants is still using the trialed vehicle. The other one no longer uses the trialed vehicle owing to a battery problem. Both of them have no plan to procure additional hybrid light buses.

(f) Solar air-conditioning system for coach: There is only one trial participant, who is still using the trialed product, but he has no plan to procure additional product.

Promotion

22. The above findings suggest that electric LGVs are likely to be suitable for taking up commercial transportation duties that are not intensive; and that hybrid vehicles are comparable with their conventional counterparts in driving performance. We will step up the promotion of these two types of vehicles by –

(a) encouraging more proactively commercial vehicle manufacturers to put on the local market their electric LGVs and hybrid LGVs; and

(b) organising more experience sharing seminars dedicated for the transport sectors that could use these vehicles in their operations.

23. Besides, we will continue to encourage the transport sectors to make use of the Fund to test out other green innovative transport technologies and their suppliers to introduce more products suitable for use by the local transport sectors.

The Trial of Hybrid Franchised Buses

24. With the Government subsidy, the FBCs that have routes operating in the urban areas commenced progressively in November 2014 a two-year trial of six double-deck hybrid buses. To monitor and assess their performance, we

have set up a Task Force, comprising representatives from the relevant FBCs, TD, as well as three experts from the local academia.

25. In terms of driving performance, the hybrid buses are comparable with conventional diesel buses. However, their fuel economy performance varies with the predominant driving modes of their routes as in the case of the hybrid vehicles trialed under the Pilot Green Transport Fund. There is also a distinct seasonal pattern. In general, the hybrid buses on highway routes with less start-stop operations tend to use more fuel; and fuel consumption in summer is higher than in cooler months. On an individual bus basis, the best performing hybrid bus delivered a fuel saving of 10.7% whereas the worst one used 9.0% more fuel. Over the two-year trial period, the hybrid buses consumed on average 0.4% more fuel than the conventional diesel buses on the same routes, which fell far short of the 30% fuel saving as reported in overseas economies. The poor fuel economy performance of the hybrid buses should mainly be due to the high air-conditioning loading in the hot and humid summer in Hong Kong, which could account for up to 40% of the fuel consumption.

26. The hybrid buses have an Euro VI engine. However, in the trial period, there were no conventional Euro VI diesel double-deck buses in Hong Kong for checking the relative emission performance of the hybrid buses. As reported in our interim report to this Panel, the average NOx emission reduction of the hybrid buses as compared with a conventional Euro V diesel bus was about 93%, which exceeded the 80% difference between the respective Euro V and VI emission limits - an indication of the NOx emission benefit of the hybrid drive train.

27. The overall daily availability of the hybrid buses was 84.1%, which is lower than the average of the conventional diesel buses at 93.6%. The relatively lower rate of availability of the hybrid buses was more evident in the initial stage of the trial owing to teething problems on the air-conditioning system and the engine system, but their performance were slightly improved in the second half of the trial (i.e. 82.6% in the first year and 85.7% in the second year). Details of the trial findings are in **Annex D.**

28. The hybrid bus manufacturer will continue to work with the FBCs to enhance the fuel economy of the six hybrid buses, despite the completion of the

two-year trial in November 2016. The following are the key improvement areas –

(a) fine-tune the control of the air-conditioning compressors and replace them with smaller ones to reduce the power demand and allow the engine to stop more frequently. The downsized compressors will not compromise the temperature of the bus saloons;

(b) replace the battery of the hybrid drive train by a larger one of a storage capacity of 32kWh (i.e. about two times bigger) to increase the storage of the energy captured from regenerative braking; and

(c) explore the feasibility to improve fuel economy by replacing their electrically driven air-conditioning units with mechanically driven air-conditioning units.

29. The price of the hybrid bus was $5.5 million each, being about 60% to 80% more costly than its conventional counterpart, which may translate into pressure for significant fare increase if bus operators are to bear the cost. The lower bus availability of hybrid buses owing to more frequent breakdowns also means that passengers may experience more service disruptions. According to the aforementioned trial results, their emission performance over Euro VI conventional buses is not substantial and their fuel economy performance in the local operation environment fell far short of expectation. As such, there is no strong justification for promoting their use in the franchised bus operation until their fuel economy performance has been significantly improved and their price has become more competitive.

30. We will continue to work with the hybrid bus manufacturer to improve the fuel economy of the six hybrid buses and closely monitor the relevant developments of hybrid buses and other green bus technologies for revisiting at suitable junctures as to whether hybrid franchised buses should be promoted.

The Trial of Electric Franchised Buses

31. The ultimate objective of the Government is to have zero emission buses running across the territory. Electric buses do not have exhaust

emissions. Replacing conventional franchised buses with electric buses can improve roadside air quality, particularly along busy corridors.

32. Compared with public buses in other cities, local franchised buses are more intensively used. They generally operate with a high operation frequency, long service hours, high peak passenger loadings, on hilly terrains, and in hot and humid summers. They also require heavy air-conditioning duties. These stringent operational conditions have put electric buses to a very severe test.

33. With the Government subsidy, the FBCs are making preparation for launching a two-year trial of 36 single-deck electric buses[5] to test out their performance, reliability as well as economic feasibility in local conditions. The electric buses include 28 battery-electric buses and eight supercapacitor buses, which will be assigned to run on different routes. Similar to the trial of hybrid franchised buses, we have set up a Task Force to monitor and assess the trial performance. The members of the Task Force are same as those of the Hybrid Bus Trial Task Force.

34. The first batch of five battery-electric buses commenced operation by the end of 2015. Since the launch of the trials, there were incidents such as malfunction of bus doors, broken wheel bolts, and excessive regenerative braking torque affecting the braking performance of electric buses in rainy weather that led to concerns over skidding on wet road surfaces, thereby rendering the actual operation of the buses to only about ten months. As such, with the endorsement of the Task Force and the consent of the electric bus manufacturer, the trial for the five battery-electric buses would be extended for five months to make up the downtime for rectification of the problems. Regarding the remaining battery-electric buses, they will commence operation progressively in 2017.

35. According to the preliminary trial results of the five battery-electric buses, the driving performance of the battery-electric buses is comparable with that of conventional buses. However, the driving ranges of electric buses might be less than those of diesel buses running on the same routes when the ambient temperature is high. For fuel economy, the electric buses could help

[5] It should be noted that the trial involves only single-deck electric bus models, while around 95% of the buses in operation in Hong Kong are double-deck buses.

save fuel cost by about 40% on the assumption that the bulk purchase diesel price is about 40% of listed price of diesel at public filling stations.

36. The second batch of five battery-electric buses for trial by Citybus Limited (CTB) and New World First Bus Services Limited (NWFB) were originally scheduled for commencement in September 2016. The trial was however put on hold as problems with the doorbells of the buses were identified shortly before the trial. Furthermore, the bus manufacturer was requested to inspect and ascertain the braking performance of the buses on wet road surfaces. It is now expected that the trial will be able to commence shortly in June this year.

37. As for the supercapacitor buses, two of them commenced the trial in late March 2017 and the operation has been satisfactory so far. The remaining six will commence operation progressively in 2017.

38. We will continue monitoring the performance of the electric buses on trial and will update the Panel in due course. Further details of the trial are in **Annex E**.

Progressively Tightening of Emission Standards for Newly Registered Vehicles

39. The Government's standing policy is to tighten motor vehicle fuel and emission standards in line with international developments when there is adequate supply of compliant fuels and vehicles in Hong Kong. With the support of this Panel, we will tighten progressively the emission standards for newly registered vehicles, starting from 1 July 2017, which will help further reduce vehicle emissions.

OUTLOOK

40. We are committed to improving roadside air quality. Apart from the above-mentioned initiatives, we will also work with the Mainland to improve regional air quality of the Pearl River Delta, which has a bearing on roadside air quality. With these efforts, we expect roadside air quality to continue the improvement trend in coming years.

Environment Bureau/Environmental Protection Department
May 2017

Annex A

Contribution of Vehicle Emissions to the Total Air Pollutant Emissions in Hong Kong in 2015

Pollutant	Contribution to Total Emissions
RSP	9%
FSP	10%
NO_x	18%
SO_2	<1%

Annex B

Roadside Concentrations of Key Air Pollutants (from 2012 to 2016) ($\mu g/m^3$)

Pollutants	Roadside Concentrations ($\mu g/m^3$)					% Difference	
	2012	2013	2014	2015	2016	2016 vs 2012	2016 vs 2015
RSP	53	57	50	45	38	-28%	-16%
FSP	36	37	32	30	26	-28%	-13%
NOx	312	321	250	227	199	-36%	-12%
NO_2	118	120	102	99	82	-31%	-17%
SO_2	10	11	9	8	7	-30%	-13%

Annex C

The Numbers of Applications for the Ex-gratia Payment (by emission standards and vehicle types) (as at 30 April 2017)

Vehicle Types	**No. of applications for ex-gratia payment (take-up rate)**					**No. of applications approved**	**Total no. of eligible DCVs**
	Pre-Euro	**Euro I**	**Euro II**	**Euro III**	**Total**		
Light goods vehicles	8,748 (89.8%)	10,176 (96.3%)	7,561 (70.9%)	4,453 (25.4%)	30,938 (63.8%)	30,690 (63%)	48,499
Medium goods vehicles	6,477 (90.2%)	2,241 (92.9%)	4,460 (73.1%)	2,922 (30.3%)	16,100 (63.5%)	15,988 (63%)	25,358
Heavy goods vehicles	657 (96.6%)	311 (99.4%)	518 (66.1%)	143 (27.9%)	1,629 (71.1%)	1,616 (71%)	2,290
Public light buses	15 (100.0%)	283 (99.0%)	138 (27.0%)	20 (4.9%)	456 (37.4%)	443 (36%)	1,218
Private light buses	297 (94.6%)	332 (93.0%)	154 (38.1%)	38 (19.5%)	821 (64.6%)	815 (64%)	1,270
Non-franchised buses	168 (94.4%)	123 (93.9%)	473 (79.5%)	1,636 (62.7%)	2,400 (68.3%)	2,367 (67%)	3,515
Total	16,362 (90.3%)	13,466 (95.7%)	13,304 (69.8%)	9,212 (29.8%)	52,344 (63.7%)	51,919 (63%)	82,150

Note: The Transport Department has stopped issuing licences to pre-Euro DCVs and Euro I DCVs since 2016 and 2017 respectively. As at 3 March 2017, all pre-Euro DCVs were phased out and only 57 Euro I DCVs still had valid licences. These Euro I DCVs will not be allowed to run on the road after the expiry of their vehicle licences.

Annex D

The Trial of Hybrid Franchised Buses
Further Details

The Trial Hybrid Buses

1. With the Government subsidy, the Kowloon Motor Bus Company (1933) Limited ("KMB"), Citybus Limited ("CTB") and New World First Bus Services Limited ("NWFB") have acquired via an open tender a total of six[6] hybrid double-deck buses for a two-year trial.

2. The selected hybrid bus is Enviro E500H Hybrid, which is a 3-axle double-deck bus produced by Alexander Dennis (Asia Pacific) Limited (ADL). The hybrid buses have an Euro VI diesel engine and cost $5.5 million each.

The Trial

3. The commencement dates, trial routes and route characteristics for the hybrid buses are as follows –

FBCs	Trial Route	Commencement Date	Route Characteristic
KMB:	1A [Star Ferry – Sau Mau Ping (Central)]	11 Nov 2014	Urban
	104 [Pak Tin – Kennedy Town]	5 Dec 2014	Urban
	619 [Shun Lee – Central (Macau Ferry)]	13 Nov 2014	Highway + Urban
CTB:	5B [Kennedy Town – Causeway Bay]	22 Nov 2014	Urban
	969 [Tin Shui Wai Town Centre – Causeway Bay (Moreton Terrace)]	6 Dec 2014	Mainly Highway
NWFB	8 [Chai Wan (Heng Fa Chuen) – Wan Chai North Temporary Public Transport Interchange]	22 Nov 2014	Urban

Trial Findings

Performance Monitoring

4. In the absence of a conventional Euro VI bus, the performance of the hybrid buses was compared with that of conventional Euro V buses (six control buses). The performance of the hybrid buses and the control buses were

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[6] Among the six hybrid franchised buses, three are operated by KMB, two by CTB and one by NWFB. The allocations of the buses were made in consideration of their bus fleet sizes.

monitored in the following five aspects in the trial –

(a) fuel consumption;
(b) urea consumption rate[7];
(c) daily bus availability;
(d) total number of on road breakdowns; and
(e) NOx emissions.

Particulates emissions were not included in the monitoring because both the hybrid buses and the control buses were designed to attain PM emission level close to the measurement instrument's measurement limits.

Overall Findings

5. A summary of the overall trial findings up to 30 November 2016 is below –

Monitoring Parameter	**Hybrid Bus**	**Control Bus**	**Hybrid Bus**	**Control Bus**	**Hybrid Bus**	**Control Bus**
	First Year Results (November 2014 to November 2015)		Second Year Results (December 2015 to November 2016)		Overall 2-year Results (November 2014 to November 2016)	
Relative Fuel Consumption	1.034	1	0.982	1	1.008	1
Relative Fuel Consumption (Excluding data affected by intercooler fault)	1.019	1	0.984	1	1.004	1
Urea Consumption Rate (% of fuel consumption)	4.5	5.2	4.5	5.1	4.5	5.1
Daily Bus Availability (%) (Excluding outage unrelated to malfunctions of the buses[8])	82.6	94.9	85.7	92.4	84.1	93.6

7 Both the hybrid buses and diesel control buses are using selective catalytic reduction devices (SCRs) to reduce NOx emissions. To support their operation, SCRs use a reagent, urea. Urea consumption rate has a bearing on their running costs.

8 The outages could be for inspections for Certificate of Road Worthiness / Certificate of Fitness, monthly inspections, routine maintenance/checking, cleaning, emission tests by Portable Emission Measurement Systems (PEMS), etc.

Average Number of On-Road Breakdowns / Month	0.32	0.04	0.13	0.08	0.22	0.06

Analysis

6. The performance of the hybrid buses are analysed below –

(a) Fuel Consumption

Overseas experiences suggest that hybrid buses could save about 30% fuel as compared with conventional buses. During the first year trial, the hybrid buses consumed on average 3.4% more fuel than the control buses. Given the poor fuel saving performance, the bus manufacturer investigated into the matter and identified a mechanical fault at the intercoolers of the hybrid buses that affected the fuel efficiency of the engines. If the data with the intercooler fault were excluded, the hybrid buses still consumed 1.9% more fuel than the control buses during the first year trial.

The bus manufacturer attempted to improve the fuel efficiency of the hybrid buses by –

(i) replacing the electric compressors of the air-conditioning system of one of the buses by smaller ones, in order to better manage the energy consumption of the air-conditioning system and allow the engines to stop more frequently;

(ii) fine-tuning the control of the air-conditioning compressor to improve energy efficiency of the air-conditioning system; and

(iii) lowering the acceleration rate of the hybrid buses to match with that of the diesel control buses.

As a result, the fuel saving performance slightly improved during the second year of the trial. The hybrid buses consumed on average 1.6% less fuel than the control buses if the data affected by the intercooler fault were excluded.

For the overall two-year results, the hybrid buses consumed on average 0.4% (excluding data affected by intercooler fault) more fuel than the control buses on the same routes, which fell far short of the 30% fuel saving as reported in overseas countries. On an individual bus basis, the best performing hybrid bus delivered a fuel saving of 10.7% whereas the worst one used 9.0% more fuel.

The overall average fuel saving of hybrid buses worsened with increase in ambient temperature. For example, the hybrid buses used about 8.8% less fuel on average than the control buses in the months with ambient temperature less than 20^oC but they consumed about 5.7% more fuel on average in the months with ambient temperature over 20^oC.

The poor fuel saving performance of hybrid buses should mainly be due to the heavy air-conditioning loading in Hong Kong, which might account for up to 40% of the fuel consumption of the buses in the summer.

(b) Urea Consumption Rate

The urea consumption rates as percentage of fuel consumption of the hybrid buses and the control buses were stable throughout the hot and cool months. The overall average urea consumption rate was 4.5% of fuel consumption for the hybrid buses, as compared to 5.1% for the control buses.

(c) Daily Bus Availability

The 93.6% availability (excluding outage unrelated to malfunctions of the buses) of the control buses outperformed the 84.1% availability of the hybrid buses.

In the first year of trial, the most common types of events reducing the daily bus availability of hybrid buses were relating to air-conditioning system and engine system.

Notwithstanding the problem of air-conditioning system still occurred intermittently, the performance of hybrid buses slightly improved in the second half of the trial (i.e. from 82.6% in the first year to 85.7% in the second year).

(d) Total Number of On Road Breakdowns[9]

The hybrid buses did not have major operational problem or breakdown in the period. However, they still had more breakdowns than the control buses. The average number of breakdown for hybrid buses was 0.22 time per month, as compared to 0.06 time per month for the control buses. Despite the difference, both rates are considered to be very low and do not constitute significant impacts to bus operation.

(e) NOx Emissions

We originally planned to compare in the two-year trial period the emissions of the hybrid buses and a conventional Euro VI bus by conducting Portable Emission Measurement Systems (PEMS) measurements. However, until the end of the two-year trial, there were no Euro VI diesel double-deck buses for the measurement.

According to the PEMS emission measurement results for the hybrid buses and the Euro V diesel control buses, the emission of NOx of the Euro VI hybrid buses were 93% lower than that of the Euro V control buses, which exceeded the 80% difference between the respective Euro V and VI emission limits. However, the difference in emission in absolute term is not significant because the Euro VI standard has already reduced the emissions of NOx to a very low level.

[9] Total number of on road breakdowns includes only failure of a passenger-carrying bus that necessitates passenger evacuation. Breakdowns for bus journeys on dead mileage are not included. Accidents are also not included.

Annex E

The Progress of the Trial of Electric Franchised Buses

Franchised bus company	No. of single-deck electric buses and manufacturer	Service route	Current status
The Kowloon Motor Bus Company (1933) Limited (KMB)	Eight supercapacitor buses (Manufacturer: China Youngman Automobile Group Company Limited)	284 [Sha Tin Central – Ravana Garden (Circular)] 5M [Kai Tak (Tak Long Estate) – Kowloon Bay Station (Circular)]	Two supercapacitor buses on Route No. 284 commenced the trial in late March 2017. Two more supercapacitor buses will be deployed to Route No.284 later this year. The trial for four supercapacitor buses on Route No. 5M would commence progressively in September 2017, subject to the progress of installation and commissioning of the charging facilities.
	Ten battery electric buses (Manufacturer: BYD Auto Industry Company Limited (BYD))	5C [Star Ferry – Tsz Wan Shan (Central)] 6C [Mei Foo – Kowloon City Ferry] 35A [Tsim Sha Tsui East – On Yam] 42A [Jordan (To Wah Road) – Cheung Hang] 603 [Ping Tin – Central (Central Ferry Piers)]	It is planned to put the battery-electric buses into service progressively in the second half of 2017.
Long Win Bus Company Limited (LWB)	Four battery-electric buses (Manufacturer: BYD)	E31 [Tung Chung (Yat Tung Estate Public Transport Terminus) – Tsuen Wan (Discovery	It is planned to put the battery-electric buses into service progressively in the second half of 2017.

		Park Bus Terminus)] S64 [Tung Chung (Yat Tung Estate Public Transport Terminus) – Airport (Passenger Terminal Building) (Circular)]	
Citybus Limited (CTB)	Six battery-electric buses (Manufacturer: BYD and Great Dragon International Corporation Limited (Great Dragon)) Three for each model	11 [Central (Central Ferry Piers) – Jardine's Lookout (Circular)] 12 [Central (Central Ferry Piers) – Robinson Road (Circular)] 25A [Wan Chai (Hong Kong Convention & Exhibition Centre Extension) – Braemar Hill (Circular)]	The first batch of five battery-electric buses from BYD commenced services on five routes on Hong Kong Island in December 2015. The five battery-electric buses from Great Dragon would tentatively commence services in June 2017.
New World First Bus Services Limited (NWFB)	Four battery-electric buses (Manufacturer: BYD and Great Dragon) Two for each model	78 [Wong Chuk Hang Station – Wah Kwai Estate (Circular)] 81 [Lai Tak Tsuen – Chai Wan (Hing Wah Estate)]	
New Lantao Bus Company (1973) Limited (NLB)	Four battery-electric buses (Manufacturer: BYD and Great Dragon) Two for each model	38 [Tung Chung (Yat Tung Estate Public Transport Terminus) – Tung Chung Station Bus Terminus (Circular)] B2 [Yuen Long Station – Shenzhen Bay Port]	It is planned to put the battery-electric buses into service progressively in the second half of 2017, subject to the progress of installation and commissioning of the charging facilities.