PUBLIC POLICY RESEARCH FUNDING SCHEME

公共政策研究資助計劃

Project Number : 項目編號：	2015.A6.058.15D
Project Title : 項目名稱：	Electrification of Single-Deck Bus and Minibus in Hong Kong 推動香港單層巴士及小巴電動化的研究
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Institution/Think Tank : 院校 ／智庫：	The Hong Kong Polytechnic University 香港理工大學
Project Duration (Month): 推行期 (月) ：	12
Funding (HK$) : 總金額 (HK$)：	700,000.00

單層巴士及小巴電動化

Public Policy Research Funding Scheme
Final Report

Date of Submission: 29 December 2016

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Project No.: 2015.A6.058.15D

Project Dates: 1 Jan 2016 – 31 December 2016

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Abstract

In pursuing sustainable development especially in major cities, promotion of public transport to take on most of the passenger travel load is a key strategy. Hong Kong is an exemplary case in promoting public transport which takes on over 80% of the commuting travelers. And, of these over twelve million trips a day, over 80% of these commuting trips are shared roughly equal by trains and buses/ minibuses. With over seven million people, Hong Kong has 7193 single-deck buses, 5779 double-deck buses and 7431 minibuses as at the end of 2015[i]. These buses and minibuses nevertheless emit 200 tonnes of PM10 and 9640 tonnes of NOx yearly[ii] contributing significantly to the air pollution especially in the crowded urban environment, posting health hazard to millions of citizens.

To improve this situation, major cities in particular in Mainland China and Europe started to look into electrifying these road public transport modes. China has pushed ahead a very strong supporting programme since 2011 to encourage e-bus and e-minibus manufacturing and utilization. Major cities like Beijing, Shanghai, Guangzhou, Shenzhen all have fixed schedules to phase out all the conventional buses in the next 10 years. India has a programme entitled “Faster Adoption and Manufacturing of (Hybrid) and Electric Vehicles (FAME). South Korea and Japan have launched e-bus trial programmes. European Community has launched the “Zero Emission Urban Bus System, ZeEUS” programme. Many European countries including UK, Germany, Belgium, France and Switzerland have initiated their own e-bus programmes. Some programmes in particular the ones in London and Shenzhen are more successful because of the very strong financial, technical and institutional supports from governments and relevant stakeholders.

The experience of e-bus programmes in Mainland China and Europe clearly demonstrates that the e-bus battery and vehicle technologies have been mature and are at a stage of large-scale applications. Thousands of e-buses are running in cities of Mainland China. Two basic types of batteries, i.e., Lithium iron and Lithium titanium are most popular. Lithium iron batteries have higher energy density, can run up to around 400 km between charge but charging time takes around 4 hours or more. Lithium titanium batteries have lower energy density, can run up to around 100 km between charge but charging time takes less than 15 minutes. Battery and vehicle have to be specially designed to fit local bus operating conditions including route length, ambient temperature, humidity and slope climbing. It is unlikely that an e-bus model can fit all operating conditions.

The major barriers of e-buses are three: i) uncertainties in performance as perceived by operators; ii) inadequate charging infrastructure and iii) uncertainties in total cost ownership (TCO) especially high capital costs.

These barriers can be overcome with a well-designed and well-supported trial which targets to clarify the uncertainties mentioned above. A strong technical team comprising battery and bus experts, operators and government to oversee the e-bus design and operation in the trial is essential. Government needs to develop the charging infrastructure. To this end, “build, operate and transfer (BOT)” model can be applied. In the meantime, education of bus operators and training of professionals to support e-bus implementation have to go hand in hand.

The successful implementation of e-bus and e-minibus in Hong Kong will provide golden opportunities to the local bus and minibus design, assembly service industries; battery and e-bus manufacturers in Mainland China as well as e-bus dealers to penetrate the bus markets in Asia and other parts of the world. Hong Kong can become centres for e-bus and e-minibus design, sales and service support centres.

[i] 2016 Annual Transport Digest, Transport Department: http://www.td.gov.hk/mini_site/atd/2016/en/section3_2.html

[ii] A Clean Air Plan for Hong Kong, Environment Bureau: http://www.enb.gov.hk/en/files/New_Air_Plan_en.pdf

摘要

世界城市為達致可持續發展，實施公共交通系統作為客運的骨幹是必然之路。香港是一個良好的典範。香港每天有超過八成人乘坐公交上學上班。在每天超過一千二百萬次公交旅程中，巴士、小巴和鐵路平均分擔了其中八成的公交乘客。超過七百萬人口，香港在 2015 年底擁有 7193 部單層巴士，5779 部雙層巴士和 7431 部小巴。而這些車輛全年排放了 200 公噸微粒和 9642 噸氮氧化物，造成嚴重的空氣污染，特別在人多擠迫的市區，對數以百萬市民的健康構成損害。

為改善這種狀況，特別是中國和歐盟的主要城市都在積極引入電動小巴和巴士。中國自 2011 年開始，大力推動電動小巴和巴士的生產和使用。中國的大城市如北京、上海、廣州和深圳都有計劃，在未來十年更換全部市區的傳統巴士。印度則有加速引入和生產新能源車計劃。南韓、日本有支持電動巴士政策，歐盟則有零排放巴士系統試驗計劃，而德國、英國、法國、瑞士等國都有自己的電動巴士項目，正在推行。這些電動巴士計劃中，以倫敦和深圳的較為成功，原因是政府、巴士營運商、車廠等持份者的大力支持，包括了財務、技術和基建上的支持。

中國和歐洲的經驗清楚說明電動車技術已步入成熟，進入一定規模使用的階段。成千上萬輛巴士在中國各大城市運作中。兩類電池最為流行，一類是磷酸鐵鋰，另一類是呔酸鋰。磷酸鐵鋰電池能源密度較高，充滿電可最多走約 400 公里，但充電時間要約 4 小時或以上。呔酸鋰電池能源密度較低，充滿電走最多走 100 公里，但充電時間少於 15 分鐘。電動巴士和其電池必須為本地特定的營運條件而設計，即行走路線長短, 環境溫度，濕度和爬坡等特點而選擇電池的類別。沒有某一款的電動巴士可以應付所有不同營運環境的。

引進電動巴士的最大障阻有三：一是對營運商而言，電動巴士的表現有不確定性，二是充電設施不足，三是在電動巴士售價高昂下，整體成本的開支不確定性。

這些障阻可以採用一個良好設計和監控的電動巴士試驗計劃，用以克服上述的不足或不確定性。引入一個強而有力的專家委員會，督導巴士車輛的設計和營運是必需的。而專家委員會應包括政府、營運商、供電商、電池和車輛專家等組成。政府也要負責發展充電設備，政府可考慮採用「興建、營運、歸還」模式，批地給私人發展商經營。與此同時，政府亦應為營運商，提供教育，亦為專業人材提供培訓課程，支援電動巴士計劃的推進。

落實電動小巴和巴士在本港使用，不單可改善空氣質素，更為香港的電動巴士設計、組裝及服務行業帶來機遇，亦為國內的電動車廠和本地的車輛推銷商打入亞洲汽車市場，以至

全球市場帶來商機。香港可成為全球電動巴士和小巴設計、營銷和支援中心。

1. Overview

Electric vehicle (EV) technology is not new and the operational principle is simple; the rotation of vehicle wheel shaft is driven not by the energy generated from a conventional internal combustion engine but an electric motor driven by a battery. The core technologies of EV are five, i.e., battery, battery management system (BMS), motor control, battery charging and vehicle body (Chan, 2016). Since 1990s, the EV technologies, driven by environmental concerns on conventional vehicles, have improved drastically. The battery energy/power density increases, the weight and volume decrease and the cost reduces. The BMS can now effectively control the battery operation safety, including mechanical, electrical, functional and chemical safety. The vehicle body weight reduces to match the statutory overall vehicle loading requirement, same for conventional vehicles. The charging system can have options of on-board charging (hybrid vehicle), plug in charging, overhead charging (pantograph) and underneath charging (induction).

The evolution of EV in the last two decades started with the hybrid vehicles whereby the battery motor traction system was placed together with the conventional engines including petrol, diesel, gas driven to ensure the driving range. World vehicle manufacturers have been very active; Nissan Leaf, Toyota Prius, Renault ZOE, i-MIEV, Porsche Boxster E, BMW i3, GM Volt have been competing strongly in the market. The ability of battery to re-collect the mechanical power during vehicle braking and deceleration; then reuse it, help save fuel consumption and thus reduce emissions. Full electric battery driven vehicle is a further step to achieve zero emissions at the point of application. With the popular application of electric hybrid vehicles, the battery and BMS technologies have been proved to be feasible and applicable. The further step to full EV is now a matter of judgment.

BYD has made a courageous step to make such a migration from HV to EV, not only on small passenger car but also on large buses – single deck to double deck buses. With the strong support of EV development from Central Government of China since 2007, EV is not a dream now and becomes a reality. There are now numerous vehicle battery and EV manufacturers in China. China has over 331,000 EVs including small to large sized vehicles on the roads as at the end of 2015. The US small EV Tesla compete very strongly especially in urban cities. Hong Kong alone has over 3000 Tesla.

Environmental Protection Department of the Hong Kong Government has been actively pursuing EV applications on public transport because they run huge mileage in crowded urban areas. Reduction of emissions from buses, minibuses and even taxis will help improve roadside air quality significantly. A trial programme was launched on electric minibus and taxis as early as 1999. The battery then was too heavy, the BMS could not control the safety of the battery to an acceptable level as well as the driving range was too short, the trial was not successful. A new round of trial on taxis and minibus were initiated under the Pilot Green Transport Fund (PGTF) which was set up in 2011. As at the end of October 2016, 3 taxis, 3 minbuses and 11 buses were funded under PGTF (Chow, 2016). Government also separately funds a trial on 36 electric buses (28 battery driven and 8 super-capacitor driven). The funds cover the installation of charging points as well.

BYD has trialed around 50 taxis in Hong Kong in 2015-2016; 3 under the PGTF scheme and others under its own initiative. The trail was not successful as only one remains running at the end of 2016 although the PGTF trial report concluded that the e-taxi can save running costs and reduce emissions. The major culprits, according to the taxi drivers, are that the driving range of the e-6 model (around 200 km) was not adequate, the charging time was too long (around 45 minutes to top up and 4 hours to fully charge) and the maintenance service was poor (takes days to repair). The BYD buses are now still on the trial but the operators were very cautious to allow the e-buses to operate even with some minor mechanical faults. It takes time to draw any conclusion.

While Hong Kong now has 6860 EVs on the road (nearly all are private vehicles), there is still very few e-buses and e-minibuses running commercially. With over seven million people, Hong Kong has 7193 single-deck buses, 5779 double-deck buses and 7431 minibuses as at the end of 2015. Many of these vehicles are still pre-Euro IV models which emit significantly more than the prevailing new Euro VI models; thus require replacement. In view of the available EV technologies and wide applications of EV on public transport especially in Mainland and Europe, it is believed that EV should be applicable to single-deck buses and minibuses as a first stage in Hong Kong. This current research looks at the very active e-bus programmes implemented in mainland China and Europe through technical visits to the manufacturers, operators, service providers and government departments; more successful experiences are drawn. Local barriers to applications of e-bus and e-minibus are identified through interviews and questionnaire survey with stakeholders. Policy recommendations are then made in the light of the findings.

The major activities of this research are summarized in Appendix A. The key components are: i) technical visits; ii) meetings with key stakeholders – individual operators and trade associations; iii) a seminar with bus and minibus operators; iv) a questionnaire survey to solicit views of all stakeholders and v) a public forum with policy makers.

2. Worldwide electric bus and minibus programmes and battery technologies

2.1 Noticeable e-bus programmes

The strongest e-bus programmes are no doubt in cities of mainland China. A very comprehensive report on "Investigation report of pure electric bus - 2012" was issued by the find800 group (www.find800.cn). The report covers 19 major Chinese cities including Beijing, Hengzhou, Guangzhou, Shanghai, Tianjin, Qingdao, Chongqing and Shenzhen. The reports provide observations of reporters in various cities. It gives positive and negative reflections from operators, passengers and drivers such as the battery life span was short (2-3 years), heavry battery resulting in energy wastage, battery temperature too high, charging time too long, and inadequate charging facilities. Chongqing was reported to have the best performance regarding the stability of the vehicle and the battery.

The wide spread of e-bus programmes in Chinese cities was sparked off by the EV policy evolved after the 2008 Beijing Olympics when the first generation of Chinese EVs were used to carry passengers in the sport grounds. Tax has been put on conventional petrol and diesel vehicles in 2008. The first set of financial policy was announced by the Ministries of Finance and Technology in January 2009 to support the development of new energy vehicles (NEV). It covered the period from 2009 to 2012. The target was to have 500,000 NEV production by the end of 2011 and 10% of NEV in new vehicle market penetration by the end of 2012. Capital and running costs of e-bus programmes were subsidized in at least 10 cities; each city would have 1000 e-buses on the road. Beijing, Shanghai and Chongqing were the first batch of cities involved.

A strengthened e-bus policy was announced in 2012. Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology (MIIT), National Development and Reform Commission were engaged. MIIT is the key agent to approve e-bus models warranted subsidies which are awarded directly to the vehicle manufacturers upon sales. The target was to have not less than 10,000 and 5,000 e-buses in mega cities and other cities in the country in the period of 2013-2015. Local governments are charged to provide charging infrastructure.

The various policies are summarized in the Table 2.1 below:

Policy Paper Title	Key Points
Vehicle production industry rationalization and development plan (2009)	Clearly spelt out the new energy vehicle (NEV) development strategy
Strengthening education and training and development of new industries strategies (2010)	Stated development of NEV as one of the seven new strategic industries to obtain national support

Energy saving and NEV production development plan (2012-2020)	Pin-pointed NEV strategy, target and supporting policies
Expediting the development of energy saving and environmental industries (2013)	Stated policy to promote innovative engineering and improvement in charging facilities
Prevention of air pollution action plan (2013)	Requested public transport, environmental bodies and government agencies to use NEVs
Guidance on accelerating extensive application of NEV (2014)	Announced 30 policies
"Made in China" strategy (2015)	Announced strengthening the nation strategies in three stages

Table 2.1: China policies of NEV

The target of NEV development by 2020 is to increase the battery energy density to 300 Wh/kg, improve the life charging cycle to 3000 but reduce the costs to 1.5 RMB/Wh. The subsidy for e-bus in 2016 ranges from RMB24,000 to 500,000 per e-bus. There will be at least 200,000 e-buses in the country (Meng, 2016).

Apart from China, India and Malaysia in Asia have been active in promoting EVs. The FAME (Faster Adoption and Manufacturing of Electric (& Hybrid) Vehicles) plans of India for 2014-2020 and targets to achieve self-sustenance by developing hybrid and electric vehicles. The Malaysian Green Technology Corporation is responsible for the national electric mobility project. It targets to achieve 10% market share of EV in transportation sector, involving 2000 e-buses mainly in Kuala Lumpur.

The European Union funds the International Association of Public Transport (UITP) EUR22.5 million to launch the ZeEUS (zero emission urban bus system) programme (2013 – 2017). The programme targets at developing fully-electric solution to the core part of the urban bus network composed of high capacity buses. It will evaluate the economic, environmental and societal feasibility of electric urban bus systems through live operational scenarios across Europe. It will facilitate the market uptake of electric buses in Europe with dedicated support tools and actions as well as support decision-makers with guidelines and tools on "if", "how" and "when" to introduce electric buses. Ten European cities including Barcelona, Bonn, Cagliari, London, Munster, Paris, Plzen, Randstad, Stockholm and Warsaw are engaged. Approximately 70 electric buses of different makes are being trialed. The revealed challenges of e-bus are that the upfront cost is much higher at around double the price of conventional bus and the battery is around 45% of the cost. The charging infrastructure is costly and the local total cost ownership models are uncertain.

Individual European countries have their own e-bus programmes; for example, Belgium's "Flemish Living Lab Electric Vehicles (2011-2015)". It targeted to stimulate the innovation and accelerate the introduction of electric mobility and to capture the future needs. French "Bus2015" programme tried to cut the Paris bus fleet's greenhouse gas emissions by 20% and carbon footprint by 50%. It targets to convert around 3600 buses to e-buses by 2025. Germany's "Electric Mobility Showcase (2012-2015)" aimed at testing 171 diesel-hybrid buses, 25 electric buses and 12 fuel cell buses regarding their suitability for practical application, energy efficiency, climate and environmental protection potential, cost-benefits and acceptance. Switzerland's "Trollybus Optimization du Systeme d'Alimentation (TOSA) (2013-) targets to realize a full-scale demonstration of the very first full electric high-capacity articulated bus running without overhead lines with feeding at bus stops. In the UK. The Transport for London started its electric bus trials in 2013 to test the availability of e-bus in London and demonstrate how it helps reducing vehicle emissions. Milton Keynes launched a wireless charged e-bus programme (2014-2019) to assess the technical and commercial viability of a wireless charging e-bus in a real world operational environment.

Across the ocean in Canada, the mayor of Windsor city launched an e-bus trail as one of the city's green energy initiatives since 2015. It targets to position Windsor as a pioneer of e-buses within its public transit system and to assist the city with its cost reduction initiatives.

In the US, the California Air Resources Board (CARB) and the National Renewable Energy Laboratory funded the Foothill Transit Battery electric Bus Demonstration program. The program was to evaluate the technology of e-buses meeting the service requirements operating in selected Foothill routes. The program concluded a success. In 2015, the US Department of Energy Resources – the Commonwealth of Massachusetts initiated the "Vehicle-to-Grid Electric School Bus" pilot program. It targets to test the feasibility of electric school bus use. Schools are funded to purchase e-bus for trials.

2.2 Observable e-bus and e-minibus models and charging facilities

The e-bus and e-minibus programmes clearly reveal that the e-buses are actually being manufactured and deployed on the road with the scale of applications ranging from a few vehicles to thousands of vehicles. Appendix B shows the internet accessible e-bus and e-minibus manufacturers. Some key manufacturers are contacted and technical visits were conducted to explore further their availability and performance.

The observed e-bus and e-minibus models during the technical visits are summarized in Appendix C and the summary is shown in Tables 2.2.1 and 2.2.2 below.

Manufacturer/ Vehicle Model	Beiqi Foton BJ6123EVCA	Chongqing Hengtong CKZ6127	Chongqing Hengtong CKZ6812HBEV	Zhengzhou Yutong E12	Suzhou Higer KLQ6129GEV	Nanjing Skywell NJL6859BEV	Nanjing Skywell NJL6121	Shanghai Sunwin SWB6121SC	BYD K9	Wrightbus StreetLite	VDL SLF 120 Electric
Dimension (mm)	12000 x 2550 x 3250	12000 x 2550 x 3385	8140 x 2200 x 2800	12000 x 2550 x 3250	12000 x 2550 x 3150	8500 x 2460 x 3120	12000 x 2500 x 3150	12000 x 2550 x 3470	12000 x 2550 x 3530	8780 x 2445 x 2990	12000 x 2550 x 3120
Energy Storage	Li-NMC	Li-Ti	Li-NMC	Li-FePO	Li-NMC	Li-NMC /Li-FePO		Supercapacitor	Li-FePO	Li-NMC	Li-Ti
No. of seats (Maximum capacity)	24–43 (70)	45 (70)	25 (50)			10-30 (66)	(72)	35 (70)	31 (68)	41 (70)	(100)
Maximum Speed (km/h)	≤69	≥80				69		70	70		
Gradeability (%)		≥16						12	≥15		
Energy Storage Capacity (kWh)	129	77.8	64.3	147/ 285	120	64.4/ 89.9	186.5	11	324	120	62.5
Charging time (min)	10	8	13	180 (285kWh)	60	/ 180	180	3	360 ~ 480	240	8 - 15
Technical Visit	Beijing, China	Chongqing, China	Chongqing, China	Zhengzhou, China	Suzhou, China	Nanjing, China	Nanjing, China(This model will be transported to Malaysia)	Shanghai, China	London, England; Shenzhen, China	Milton Keynes, England	Munster, Germany

Table 2.2.1: e-buses observed during the technical visits to China and Europe

Manufacturer/ Vehicle Model	Beiqi Foton BJ6650EVCA	Nanjing Skywell NJL6706BEV	Changjiang EV e Boss	Suzhou Higer KLQ6702EV	Zhengzhou Yutong E6	Nu Track City Dash	Nu Track City Lift
Dimension (mm)	6530 x 2230 x 2830	7000 x 2050 x 2780	6810/ 7490/ 8310 x 2195 x 2790	7020 x 2040 x 2790	6395 x 2065 x 2930	7500x 2240 x 2790	7380 x 2260 x 2920
Energy Storage		Li-FePO	Li-FePO				
No. of seats (Maximum capacity)	11 – 15 (36)	21	10-19/ 10-22/ 10-25	(22)	10 – 19 (26)	16	16
Maximum Speed (km/h)		80	≥130				
Gradeability (%)		≥20%	31				
Energy Storage Capacity (kWh)		67.8	76 (6810mm)/ 96 (7490mm)				
Charging time (min)		240	On-board: 360/ 480 Fast charging: 60				
Technical Visit	Beijing, China	Nanjing, China	Hangzhou, China	Suzhou, China	Zhangzhou, China	Belfast, UK	Belfast, UK

Table 2.2.2: e-minibuses observed during the technical visits in China and Europe

The e-buses are single deck buses with length ranging from 8 m to 12 m; capacity ranging from 50 to 70 passengers and battery capacity ranging from 64.3 kWh to 285 kWh depending on the type of battery installed. The e-minibuses have the vehicle length ranging from 6.4m to 7.0m with capacity ranging from 10 to 36 passengers. The battery capacity ranges from 68 kWh to 76kWh.

These capacities are improving. At January 2017, it is stated in manufacturers' websites (Yutong and King Long (Higer and King Long Xiemen) adopting the LiFePo battery) that the driving range in city cycle is about 230 (250) km with AC or 300 (320) km without AC. The battery capacity ranges from 295 to 324 kWh. And, 400 DD e-bus (12.8 m) have been delivered from Zhuhai Yin Tong to Beijing in June 2016 as well as 5 BYD DD eB-bs (10.4 m) have started trial in London in 2016.

The battery types are three, i.e., Lithium NMC (nickel, magnesium and cobalt oxide); Lithium Titanate; Lithium Iron Phosphate.

There are slow (Lithium Iron Phosphate battery), fast (Lithium NMC battery) and ultra-fast (Lithium Titanate battery) charging facilities. For slow charging, the charging electric current is 63-150A at 380-400V; the charging time is around 3-8 hours. For fast charging, the charging electric current is 260A at 600V. For the ultra-fast charging, the charging electric current is 400A at 700V and takes around 10 minutes to charge each time. The 12m e-bus in Chongqing was observed to take 9 minutes to charge from SOC at 60% to 100%.

There are plug-in battery charging, inductive charging and pantograph charging facilities. The plug-in charging gun requires the bus driver or an operator to serve the charging while the other two facilities are automatic when the alignment is correct.

Super-capacitor buses (12-meter-long carrying 70 passengers) were observed in Shanghai. The super-capacitor has 30 kWh capacity. The buses were charged with pantograph at bus stops and termini. The charging current was 150-200A at 600V. The charging time is around 3 minutes.

2.3 Battery types and characteristics

Battery determines the e-bus performance. It is crucial to make a correct choice of type and size of the battery to ensure the best bus performance along service routes. The prevailing battery types and characteristics are summarized in Tables 2.3.1 and 2.3.2.

Battery/ Supercap	Lithium Manganese Oxide	Lithium Nickel Manganese Cobalt Oxide	Lithium Iron Phosphate	Lithium Nickel Cobalt Aluminum Oxide	Lithium Titanate	Supercapacitor
Voltage	3.70V (3.80V) nominal; typical operating range 3.0–4.2V/cell	3.60V, 3.70V nominal; typical operating range 3.0–4.2V/cell, or higher	3.20, 3.30V nominal; typical operating range 2.5–3.65V/cell	3.60V nominal; typical operating range 3.0–4.2V/cell	2.40V nominal; typical operating range 1.8–2.85V/cell	2.40V nominal; typical operating range 1.0–2.8V/cell
Specific Energy (Capacity)	100–150Wh/kg	150–220Wh/kg	90–120Wh/kg	200-260Wh/kg	70–80Wh/kg	~5 to 15 Wh/kg (typical) it is low as compared with battery,
Charge (C rate)	0.7–1C typical, 3C maximum, charges to 4.20V (most cells)	0.7–4C, charges to 4.20V, some go to 4.30V; 3h charge typical. Charge current above 1C may shorten life.	1C typical, charges to 3.65V; 3h charge time typical	0.7C, charges to 4.20V (most cells), 3h charge typical, fast charge possible with some cells	1C typical; 6C* maximum, charges to 2.85V	3C
Discharge (C rate)	1C; 10C possible with some cells, 30C pulse (5s), 2.50V cut-off	1C possible on some cells; 2.50V cut-off	1C, 25C on some cells; 40A pulse (2s); 2.50V cut-off (lower that 2V causes damage)	1C typical; 3.00V cut-off; high discharge rate shortens battery life	10C possible, 30C 5s pulse; 1.80V cut-off on LCO/LTO	
Cycle Life	~300–700 (related to depth of discharge, temperature)	~1000–10,000* (related to depth of discharge & temp.)	~1,000–2,000 (related to depth of discharge, temperature)	~500-1,000 (related to depth of discharge, temperature)	~5,000-20,000	~4,000-50,000

Table 2.3.1: e-bus battery types and characteristics

Battery/ Supercap	Lithium Manganese Oxide	Lithium Nickel Manganese Cobalt Oxide	Lithium Iron Phosphate	Lithium Nickel Cobalt Aluminum Oxide	Lithium Titanate	Supercapacitor
Thermal Runaway	250°C (482°F) typical. High charge may promote thermal runaway	210°C (410°F) typical. High charge may promote thermal runaway	270°C (518°F) Very safe battery even if fully charged	150°C (302°F) typical, High charge may promote thermal runaway	One of the safest Li-ion batteries	Low internal resistance, hence relatively less heat generated during high current operation., hence safe
Applications	Power tools, medical devices, electric powertrains. Example in E-Bus project: Chongqing	E-bikes, medical devices, EVs, industrial Example in E-Bus project: Suzhou	Portable and stationary needing high load currents and endurance. Example in E-Bus project: Shenzhen	Medical devices, industrial, electric powertrain (Tesla)	UPS, electric powertrain (Mitsubishi i-MiEV, Honda Fit EV), solar-powered street lighting. Example in E-Bus project: Munster of Germany	UPS, DVR (dynamic voltage restorer) in power system, load leveling system in buildings. Example in E-Bus: Shanghai E-Bus project
Comments	High power but less capacity; safer than Li-cobalt; commonly mixed with NMC to improve performance.	Provides high capacity and high power. Serves as Hybrid Cell. Favorite chemistry for many uses; market share is increasing.	Very flat voltage discharge curve but low capacity. One of safest Li-ions. Used for special markets. Elevated self-discharge.	Shares similarities with Li-cobalt. Serves as Energy Cell.	Very long life, fast charge, wide temperature range but low specific energy and expensive. Among safest Li-ion batteries.	Super long life, ultra-fast charging, operation not much depends on temperature, hence wide operating temperature range. But very low specific energy and expensive. Energy stored a Voltage.

Table 2.3.2: e-bus battery types and characteristics

As shown in Table 2.3.1, there are five types of battery and the super-capacitor is listed for comparison purpose.

Lithium titanate and lithium iron phosphate are the safest battery types with minimum thermal runaway. Lithium titanate has the least specific energy, the highest cycle use (longest life span) but the most expensive type of battery. Lithium iron phosphate is the most popular because of its lower cost and its specific energy is roughly 50% higher than that of lithium titanate; however, its cycle use is much less.

The other three types of battery all have problems of thermal runaway which have to be controlled to achieve the safety standard. They are cheaper than lithium titanate but more expensive than lithium iron phosphate. However, they can have higher power and better performance than lithium iron phosphate. The cycle use of lithium NMC can achieve a few times longer than lithium iron phosphate but still shorter than that of lithium titanate.

The charging characteristics of these battery types are shown in Table 2.3.3. Their major advantages and disadvantages are summarized in Table 2.3.4.

Mode		Ultra fast Charging	Fast Charging	Slow Charging	Battery Swapping	Trolley Bus
Description		The batteries is recharged in the E-bus. The charge rate is over 6C	The batteries is recharged in the E-bus. The charge rate is over 1C	The batteries is recharged in the E-bus. The charge rate is less than 0.5C	Batteries are charged in a battery charging station. Batteries are swapped between vehicle body and battery charging equipment	Vehicles can be charged by the electrical grid during operation. Vehicles can disconnect from electric grid and consume the energy stored in batteries, until vehicles connect with the electric grid again
Features	Charging	Charging batteries installed in the vehicle	Charging batteries installed in the vehicle	Charging batteries installed in the vehicle	Batteries are swapped from vehicle to charging box, and charged inside the box	Buses draw power from overhead wires
	Charging facility	Charging gun, at least 6C	Charging gun over 2C	Charging gun, equal or less than 0.5C	Specialized charging equipment	Dedicated cable
	Duration	From 10 to 15 mins	From 0.5 to 2 hours in general	From 4 to 8 hours in general	From 8 to 15 minutes in general	Charging during operation
	Operation	Charging at bus termini	Moderate distance	High bus turnout rate; unsuitable condition for installation of charging equipment	Long single travel distance	A city with cable or trackless tram

Table 2.3.3: Charging characteristics of batteries

There are five charging modes: ultra-fast, fast, slow, battery swapping and overhead cable (trolley bus). The charging rate of ultra-fast, fast and slow charging mode is over 6C, 1C and less than 0.5C resulting in charging time of 10-15 minutes, 0.5-2 hours and 4-8 hours respectively. The battery swapping mode requires the battery to be charged at dedicated stations with special handling equipment; the operation takes around 15 minutes. The overhead cable charging mode charges the e-bus battery when the bus antennae connects the cable.

With these characteristics, one ultra-fast charging point, similar to that in conventional gas stations, can serve many buses while one slow charging point can only serve one bus during the overnight charging. Cost and land requirements vary significantly in installing charging infrastructure for different modes of charging, probably in the order overhead cable, ultra-fast, fast, slow and battery swapping.

Mode		Ultra fast Charging	Fast Charging	Slow Charging	Battery Swapping	Trolley Bus
Example of Energy storage		Lithium Titanate, Lithium NMC	Lithium Titanate, Lithium NMC	Lithium Iron Phosphate	Lithium Iron Phosphate	Super capacitor
City Experience		Beijing, Chongqing, Munster, Nanjing,	Suzhou	London, Shenzhen, Zhengzhou	Qingdao, Zhengzhou	Shanghai
Comparison	Advantage	A charging gun can serve about 10 E-bus daily. A long life span battery is required. Smaller spaces are needed to install chargers.		The number of charging gun has to be comparable to the number of E-bus	The duration of battery swapping is short, buses be in operation again quickly; the charging environment must be fit to the requirement of batteries	Cable is a kind of one time investment. The overall operation cost is low and the whole system is sustainable
	Disadvantage	E-buses are needed to be charged during the daytime. It might affect the grid.	E-buses are needed to be charged during the daytime. It might affect the grid.	In order to achieve the long traveling distance, it causes increasing in weight of vehicle and the buying cost, as more batteries are installed. Larger spaces are needed to install chargers.	The battery swapping and charging station is large in size, as it includes battery charging boxes and mechanical equipment for swapping batteries. The construction period is relatively longer than other charging modes. The overall cost is high. The vehicle to battery set ratio is 1:1.2.	Cable might have negative impact on aesthetic appeal of city. The limitation of operation is relatively larger than other charging modes. The planning and construction might take longer time than other charging modes.

Table 2.3.4: Advantages and disadvantages of charging modes

As shown in Table 2.3.4, cities choose various battery charging modes taking their major advantages which may meet their needs better. Table 2.3.4 also shows the battery types compatible to the charging mode. The major disadvantage of ultra-fast charging is that the battery requires more frequent charging in the day time which may affect the power supply especially at the peak demand of the city. The slow charging battery will have heavier weight on the bus and thus reduce its energy efficiency per passenger carried while battery swapping and overhead cable have their constraints in land, equipment and aesthetic issues.

3. Experience of more successful electric bus and minibus programmes

In running either the trial e-bus programmes or the full implementation of e-bus operation, some cities are more successful than others. Owing to the high upfront costs (e-bus and charging facilities), all governments have to subsidize the upfront costs and some governments have to subsidize even the running costs in order to launch the trial programmes. Out of the cities visited in the technical visits, Shenzhen, Chongqing and London are more successful examples of e-bus programmes.

Shenzhen

Shenzhen government takes on the full responsibility of implementing e-bus programme. It targets to phase out all conventional buses (over 10,000 in total) in 2017. Apart from the subsidy from central Government, Shenzhen government injects RMB500 million every year to support the development of e-bus programme including e-bus purchasing, operating and installing charging infrastructure. The maximum subsidy for e-bus purchase from central Government is RMB500,000 per vehicle and Shenzhen Government also matches the subsidy to make it RMB 1 million per vehicle in total. For the bus operator, they pay around RMB 1million to buy a BYD e-bus. Shenzhen Government further subsidizes the operator RMB450,000 per vehicle when the e-bus runs over 60000 km per year. The electricity price is also controlled at a level below RMB 1 per kWh. There were over 3000 e-buses running in Shenzhen at March 2016; most are BYD buses.

Based in Shenzhen, BYD is in full cooperation with the Shenzhen Government in producing e-bus to meet the need of the bus operators. As BYD also provides the charging infrastructure, the defects of bus or the charging are sorted out at the spot; downtime is reduced to the minimum.

BYD e-bus adopts the slow charging lithium iron phosphate battery, Shenzhen Government is now building 13 multi-storeys bus depots for charging the e-buses. The target is one "charging gun" per e-bus; and a total of 26 such depot buildings have to be built. The Government also plans to develop e-bus charging network along major routes, targeting at one e-bus charging point per 5 km^2.

With all these supports, the Shenzhen East Bus operator, one of the two biggest local operators, was happy with the e-bus programme although there were some teething problems such as defect in the BMS and other mechanical faults that require 20% more e-buses in the fleet to provide same service level as the conventional buses. The workload on vehicle maintenance was reduced and the drivers are happy with the e-buses.

Chongqing

Although there are only 46 e-buses in operation in Chongqing in April 2016, 31 of these e-buses have been running since 2011 and the battery degradation is only around 6%. It is observed that the power consumption of an e-bus is 1.46 Wh/km on slope climbing (around 10%) the SOC at 61% is charged to 100% in 9 minutes 33 second. The bus battery is lithium titanate.

The bus operator and the drivers are happy with the performance of the e-buses although there is no subsidy from the Government. CNG buses forms the majority of the bus fleet in Chongqing as CNG buses and CNG are cheap there. Central Government only subsidizes slow-charging e-buses at the time because slow-charging buses require charging overnight and do not compete for power in the day time.

The e-buses perform better than the conventional buses. The battery and the vehicle manufacturers (they were in one consortium) have been very attentive to rectify any discrepancies. The charging infrastructure is tendered out to TELD, one of the biggest charging service provider in the country.

London

The e-bus programme is initiated by Transport for London (TfL), a corporation under the city government. The bus fleet of London is around 9000 vehicles in some 700 routes. TfL tenders the bus operation out in groups of routes to private operators. 1700 buses are now operated with hybrid (diesel-electric) buses. The main incentive of electrifying buses is the implementation of Ultra Low Emission Zones (ULEZ) in London whereby all single deck buses will be zero emission buses and double deck buses will be Euro VI hybrid by 2019.

To meet with the challenge of low/ zero emissions and optimize the business opportunity, a partnership group named Low Carbon Vehicle Partnership (LowCVP) was established in the UK in 2003 to accelerate a sustainable shift to lower carbon vehicles and fuels, and create opportunities for UK business. Nearly 200 organizations are engaged and the Bus Working Group has over 50 active members (Weston, 2016).

As at the end of 2016, 73 pure e-buses are in service in London. E-bus suppliers include BYD, BYD/ADL, Optare and Irizar. 51 BYD single deck e-buses are in service in light duty routes (4-5 hours service a day). 5 BYD double deck e-buses are being trialed too. The Southern Electric Energy, one of the biggest energy supplier in the UK in collaboration with the UK Power, develops the charging infrastructure for e-buses. The e-bus manufacturers and the charging facility service provider are required to be attentive to the trial of the e-buses.

Summary

The experiences of more successful e-bus programmes reveal that there can be a number of models in driving the e-bus programmes.

The government in Shenzhen is the main driving force which demands the full collaboration of the vehicle/battery manufacturer and the bus operator. The three main stakeholders work as a consortium to ensure the smooth implementation of the e-bus programme.

In the case of Chongqing, the main driving force is the battery and vehicle manufacturer. Government grants land for charging station installation only. The battery/ vehicle manufacturers and the charging service provider work closely together with the bus operator to ensure the smooth implementation of the e-bus programme.

In the case of London, the public corporation is the main driving force. Through open tendering process and contractual terms, the battery/ vehicle manufacturers and the charging service providers have to work together closely with the bus operator to ensure the success of the e-bus trial programme.

4. Major barriers

Major barriers to electric commercial vehicle (ECV) adoption have been identified by many researchers as summarized in Table 4.1. Barriers can be divided into three main categories, namely technology, finance and operation. Financial/ operational and technological aspects of ECV adoption are equally important in decision making. Researches focused on barrier studies indicate the negative impact of these barriers on operator' incentives toward commercial vehicle electrification.

<table>
<tr><th colspan="3">Major Barriers</th><th>Reference</th></tr>
<tr><td colspan="2">Technological Barriers</td><td>Variation in Energy Efficiency depending on driving cycle and bus configuration</td><td>Lajunen, 2014</td></tr>
<tr><td colspan="2">Financial Barriers</td><td>• Uncertainty over TCO,
• Lack of supporting legislation,
• No Financial Incentives</td><td>Bae et al. (2011),
Conti, Kotter and Putrus (2015),
Kaplan et al. (2016),
Kirk, Bristow and Zanni (2014),
Kühne (2010),
Lajunen (2014),
Musso and Corazza, 2015,
Sierzchula (2014),</td></tr>
<tr><td rowspan="2">Operational Barriers</td><td>Barriers of Charging</td><td>• Large number and distribution of charging infrastructure for opportunity charging,
• Relatively long refueling/ recharging time</td><td rowspan="2">Kakuhama et al., 2011
Lajunen, 2014,
Mahmoud et al., 2016,
Pihlatie et al., 2014,</td></tr>
<tr><td>Barriers of Operation</td><td>• Specific ECV Models for Specific Routes,
• Lower Flexibility in Scheduling</td></tr>
</table>

Table 4.1: Major barriers to commercial EV adoption

The ECV technology has improved significantly over the years. The performance of energy storage in terms of power and energy capacity, which was the biggest technological barriers, is greatly enhanced by the more mature lithium-ion battery technology (Burke and Miller, 2011; Scrosati and Garche, 2010). Power and energy capacity improvement enhance the feasibility of electric commercial vehicle operation. However, the energy efficiency has considerable variation depending on driving cycle and bus configuration (Lajunen, 2014).

Uncertainty over total cost of ownership (TCO), lack of supporting legislation and no financial incentives are the major financial barriers (Conti, Kotter and Putrus, 2015; Lajunen, 2014 and Kühne, 2010). The uncertainties were derived from manufactured price, maintenance cost, end-of-life, infrastructure, emission and insurance. Procurement intention is reduced by the significant uncertainty over TCO, as TCO of each e-bus cannot be properly quantified and applied in business model. Bae et al. (2011), Kaplan et al. (2016), Kirk, Bristow and Zanni (2014) and Sierzchula (2014) studied the barriers of purchase of ECVs in firm level and important role of government in ECV adoption. The theoretical model created by Bae et al. (2011) shows that government subsidies, energy price shocks, energy savings and environmental regulations can be drivers towards EVC adoption, while Sierzhcula (2014) shows that governmental grants and first-mover advantage could have great impact on profit-seeking companies. It is found from the interviews of 17 stakeholders (Kirk et al., 2014) that fuel costs, refueling infrastructure, vehicle purchase cost and residual value, the removal of the London congestion charge exemption, lack of knowledge regarding EV and vehicle weight are possible motivating factors and barriers underlying purchase of ECVs. A model based on Theory of Planned Behaviour with the basis of 1443 responses from a large-scale survey in Austria, Denmark and Germany (Kaplan et al., 2016) shows that energy cost savings, environmental benefits, parking benefits, good company image and driving ease are relatively important in purchase intentions of ECVs. The attitudes of stakeholders towards innovative measures are studied as part of the European Bus System of the Future (EPSF) project. The result is clear that innovative measures, leading to reduced fuel consumption or improved service efficiency, might be accepted and applied on condition that operation costs are not increased (Musso and Corazza, 2015).

The core operational limitation of ECV adoption is flexibility in operation. The flexibility in operation are greatly limited by the features of ECVs. Specific ECV models for different routes are required in order to maximize performance and cost efficiency (Lajunen, 2014 and Pihlatie et al., 2014). As specific ECVs are only energy/ cost-effective in specific route, it reduces the flexibility in scheduling and operation comparing to diesel vehicles. **Battery electric buses (BEBs)**, in particular, are questioned in flexibility in operation due to the influence of charging time on schedule (Miles and Potter, 2014). Miles and Potter (2014) estimated that all electric buses provide the similar performance as diesel bus based on range extension by 5min refueling/ recharging, except overnight BEB. It seems BEB opportunity charging has smaller impact on operation than overnight BEB, as it can be achieved by various choices of charging infrastructure including charging spots, pantograph charging and inductive charging (Mahmoud et al., 2016). Although only minor modification to the current infrastructure is needed for BEB opportunity, the considerable number and distribution of infrastructure is a barrier to implementation (Kakuhama et al., 2011).

To confirm these barriers to e-bus introduction to Hong Kong, local bus and minibus operators (individual operators and associations) were consulted through series of meetings, seminar and public forum. The major barriers in the Hong Kong context are summarized in Table 4.2.

To the bus and minibus operators, there are two major uncertainties, one is technical and the other is financial. These uncertainties, to a very large extent, is derived from the lack of knowledge of the prevailing technological levels of the e-bus technologies and performance and the unhappy experience of previous e-bus and e-minibus trials in Hong Kong. Previous trials have not been organized based on the experience of more successful examples stipulated in Section 3 of this report.

Technological Obstacles		• Battery Safety • Driving Range Anxiety
Operational Obstacles	Obstacles to Charging	• Relatively Long Charging time (Insufficient Charging Facility is one of the reasons) • Lack of Space in Termini for charging facilities • Limited numbers of Public Charging Facilities
	Obstacles to Fleet Management	• Pressure on Operation due to Uncertain Downtime • Uncertainty over Scheduling • Limitation on Vehicular Licenses • Spare Buses are needed (more) • Availability of service support
	Others	• Lack of Maintenance Technicians Specialized on EV • Battery/ Electric Component Waste Management • Safety of Pedestrians and Cyclists due to Reduced Operational Noise,
Financial Obstacles		• High Upfront Cost • Trade-offs between Efficiency, Size and Price (Battery Types, Interior Volume) • High Uncertainty over TCO

Table 4.2: Major barriers to e-bus programme in Hong Kong

5. Policy recommendations

To formulate policies to overcome the identified technical, operational and financial barriers to e-bus programme, a seminar and a public forum were organized. The seminar was targeted at bus and Minibus operators, government officials, power companies, academics while the public forum invited policy makers, power company, e-bus dealers, e-bus developers, charging service providers and green groups to attend. Both seminar and open forum were well attended (refer to Appendix A). For the seminar, there were a total of 31 attendees (4 academics, 14 bus operator, 1 minibus operator, 2 EPD staff, 5 from the two power companies and 5 from consultant companies). For the public forum, there is a total of 41 attendees (2 legislative councilors, 11 district councilors covering 7 districts, 6 green group representatives (5 groups), 10 e-bus dealers (6 companies), 1 charging facilities provider and power company, 6 from higher education institutions, 4 from a e-bus developer and 1 from a newspaper).

To enhance informed consultation, materials of e-bus, battery technologies and charging mode comparison were compiled and distributed to all the registered participants. A questionnaire on policy proposal was included in the pile of consultative document. The notices of seminar and public forum as well as the consultative document are appended to Appendix D. A total of 56 completed questionnaires were obtained from the seminar and public forum. The analysis of questionnaire results is included in Appendix E.

For the technical barriers, 79.6%, 51.9% and 63.6% respondents considered charging time, convenience of charging as well as battery life respectively to be most important. 80.8% and 50.9% of respondents considered the night-time charging plus one day-time charging as well as day time charging a number of times to be feasible charging pattern to fit the bus operation. The percentages for minibus was 67.9% and 63.5%. Less than 40% respondents considered swapping battery nor super-capacitor feasible.

For the financial barriers, 63.6% and 57.4% respondents considered the price of e-bus or the charging infrastructure respectively the most important determinant in e-bus and e-minibus programmes. 71.2% and 59.6% respondents considered the government and the bus/minibus operators should share the e-bus/ e-minibus purchasing costs. And most respondents considered that government and the charging facility providers should bear the costs of power supplier and charging infrastructure.

Through technical visits, meetings and communications with e-bus and e-minibus developers, manufacturers and dealers as well as the charging facilities suppliers, it is clear that:

1) The e-bus technology composes of a) vehicle, b) battery, c) BMS and d) charging technologies. **These technologies are mature and ready to apply in large scale** as reflected in the cases of mainland China and Europe.
2) The e-bus manufacturers in mainland China have invested significantly in developing b), c) and d); however, a) is the weakest while manufacturers elsewhere (in particular EU) are good at a) as they have lots of experience in vehicle design and manufacturing.
3) Although the battery and vehicle technologies have mature but the design and manufacturing of e-bus, i.e., determining the optimum type and amount of battery and vehicle compartment configuration to meet prevailing specification to suit bus operation requirements, is still at a developing stage. Apparently, no e-bus manufacturer is good at all the 4 component technologies to ensure an e-bus meeting the operators' requirements. As such, **there are ample rooms for collaborations among these manufacturers**. The collaboration of BYD in China and ADL in UK (good at vehicle body design and manufacturing) to develop double deck buses for London is a good start. Through many failure experience in e-bus trials for years especially in mainland China, successful experiences have emerged. However, these experience has not been passed to Hong Kong.
4) **For the case of Hong Kong, there is a big knowledge gap in e-bus technologies and total cost in ownership (TCO)** especially among the bus operators. The e-bus knowledge is over-shadowed by negative reports of battery thermal runaway in early trials in mainland China and the unsuccessful experience in very small-scale ill-organized local trials.
5) **The limited number of e-buses trialed or being trialed in Hong Kong have not been properly designed to meet the operating conditions for Hong Kong.** And, there is no local technical support to oversee and drive the trials to a success. Trials so far disappoint the operators and give rise to the ill impression of e-bus.
6) The e-bus and e-minibus manufacturers are not willing to design, manufacture and provide maintenance service to e-bus if the ordered number for these vehicle is too small. With the Government's financial supports to e-bus and e-minibus trials, the e-bus and e-minibus dealers in Hong Kong are very active to sell available vehicle models (all from mainland China). However, these models can only be picked out of the shelf. It would be extremely lucky if an e-bus model can meet the operational requirements of the local operators.
7) There are some parties (academic, HKPC and GMI) in Hong Kong exploring e-bus and e-minibus technologies. There are some successes in developing charging facilities; for examples, the SmartCharge and the HK EV-Power. HKPC tries to collaborate with manufacturers from mainland China to develop an e-minibus; GMI has developed an e-minibus charged on board by a diesel engine. **There is no collaboration between all key**

stakeholders, i.e., government, bus operator, e-bus manufacturer, battery manufacturer and charging facility provider to ensure a successful e-bus programme.

8) The bus and minibus operators have desire to try e-bus/ e-minibus because of the obvious savings and fuel and maintenance costs; However, the high capital costs; uncertainties of downtime are major hurdles.

There is a golden opportunity for Hong Kong in developing e-bus models and programmes to meet local operation requirements. The opportunity exists in the following areas:

1) Hong Kong is good at forge collaboration between mainland China and the other parts of the world to formulate good business models. There is a huge market in world cities for e-bus. Mainland China is very strong now in battery and charging technologies but weak in vehicle design. Europe is the reverse.
2) Hong Kong can be the first world city to fully implement a successful e-bus programme in market economy. This can be achieved through a properly designed and supervised e-bus trial with a sizeable fleet. As an exemplary city in public transport and electrified public transport system, Hong Kong is in the best position to become a trading centre of e-buses for other parts of the world. The Chinese battery and e-bus manufacturers as well as local e-bus charging facility providers and vehicle dealers will be benefited.
3) With proper education and training, Hong Kong can become a base to service e-bus programmes locally and overseas. Hong Kong is good at formulate value added services. This will create significant job opportunities.

To grasp this golden opportunity, the Government should adopt the following policy:

1) To strengthen the current supports, including financial, land provision and technical supports, to e-buses. In the first stage, Government should formulate a new e-bus programme (described below) to ensure the right policy direction.
2) To enable a good business environment for forging collaborations among battery and e-bus manufacturers in mainland China and European vehicle manufacturers. The relevant policy bureaus, in particular the Transport and Housing Bureau, the Environmental Bureau and Commerce and Economic Development Bureau have to be charged with definite responsibilities to create collaborative opportunities for e-bus trade sectors in Hong Kong, Mainland and Europe.
3) To support education and training of professionals and technicians for the e-bus and e-minibus service sectors to ensure adequate manpower for this new trade.

To push the policy on electrifying public transport ahead and based on the experience of successful e-bus programmes described in this report, a sizable trial of e-bus and e-minibus should be properly mounted up.

The number of vehicles has to be sizable to ensure the manufacturers' willingness to collaborate. The main purpose of the trial is to demonstrate the major technical and financial barriers to e-bus perceived by operators can be tackled. To overcome the technical barriers, the vehicles together with the battery and charging infrastructure have to be properly designed, manufactured and serviced. There must be a competent driving force to ensure the success of the trial. As such, an e-bus committee of experts should be formed to drive the e-bus and e-minibus trial programmes. The committee of experts should be responsible for all technical matters, including:

- Develop vehicle specifications and charging equipment specifications for local electric buses and minibuses

- Collect operational information on franchised buses, non-franchised buses and minibuses to determine battery and charging requirements and best combinations of batteries and charging modes
- Work together with vehicle manufacturers, battery suppliers, charging service providers to ensure the best production and service packages
- Select trial routes and distribution of vehicles
- Collect and analyze the operational data of the trial; and to improve the design and services of the vehicles
- Clarify the e-bus total costs of ownership (TCO) is better than that of the conventional vehicles (an initial comparison of TCO of e-bus/ e-minibus is included in Appendix F)

The institutional set-up of this Committee of experts is illustrated in Figure 5.1. It should be under the existing EV Steering Committee chaired by the Finance Secretary.

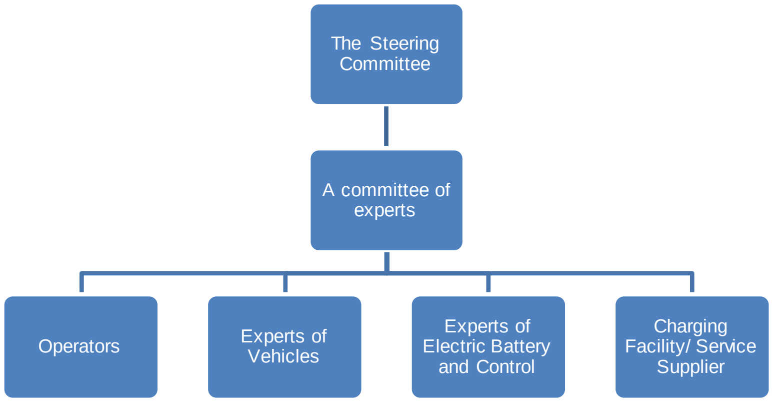

Figure 5.1: the set-up of the Committee of Experts for e-bus trial programme

In order to facilitate the trial programme, the Government should:

- Bear the monetary cost of e-bus/ minibus in trial
- Install the charging facilities for the e-bus programme, an option is to employ the "Build, Operate and Transfer (BOT) model to tender out to charging facilities providers as long as the locations of charging points are agreed with bus operators
- Issue temporary licenses for e-bus/ minibus in trial if necessary

Assuming 100 e-buses and 100 e-minibuses in the trial, the total financial commitment (excluding the land requirements) from Government is calculated as shown in Table 5.1.

Scenarios	Type of Charging Modes	Manufacturer	Type of Vehicles	No. of SC Ebs	No. of UC Ebs	Total Cost of Ebs (HKD)	No. of Low Power Charger	No. of High Power Charger	Total cost of Chargers (HKD)	Total Cost of Scenarios (HKD)	
Scenario A	Slow Charging (SC)	Chinese made	12m Electric SD Bus	100	0	$225,120,000.00	100	0	$8,400,000.00	$233,520,000.00	Total Cost of Scenarios A
			Electric Minibus	100	0	$105,000,000.00	100	0	$8,400,000.00	$113,400,000.00	$346,920,000.00
Scenario B		Foreign made	12m Electric SD Bus	100	0	$457,609,900.00	100	0	$8,400,000.00	$466,009,900.00	
Scenario C	Ultra-fast Charging (UC)	Chinese made	12m Electric SD Bus	0	100	$195,000,000.00	0	17	$11,900,000.00	$206,900,000.00	
Scenario D		Foreign made	12m Electric SD Bus	0	100	$361,000,000.00	0	17	$11,900,000.00	$372,900,000.00	
Scenario E	50%SC & 50%UC	Chinese made	12m Electric SD Bus	50	50	$210,060,000.00	50	9	$10,500,000.00	$220,560,000.00	
Scenario F		Foreign made	12m Electric SD Bus	50	50	$409,304,950.00	50	9	$10,500,000.00	$419,804,950.00	

Table 5.1: Financial commitment of e-bus and e-minibus trial programmes

The total costs of the e-bus trial programme range from HKD207 million to HKD640 million depending on the vehicle make (Chinese or foreign) and the charging mode (ultra-fast of slow). The total costs of e-minibus trial programme is HKD113 million (a Chinese make and slow charging).

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Appendix A: Research activities

Table 1 lists the research activities in achieving the project objectives while Table 2 provides further details of each activities.

Table1) Research Activities

Date	Activities
28 DEC 2015	Meeting 1 – China Road Transport Association
26 FEB 2016	Team Meeting 1
10 MAR 2016	Technical Visit 1 – Shenzhen
23 – 26 MAR 2016	Technical Visit 2 – Beijing & Qingdao
13 APR 2016	Technical Visit 3 – Chongqing
19 APR 2016	Technical Visit 4 – Zhengzhou
5 MAY 2016	Team Meeting 2
22 – 27 MAY 2016	Technical Visit 5 – Brussels, Munster, London & Bellfast
31 MAY 2016	Meeting 2 – E-bus Manufacturer & Local Vehicle Dealer
10 JUN 2016	Team Meeting 3
12 – 17 JUN 2016	Technical Visit 6 – Nanjing, Suzhou, Shanghai, Wuzhou & Hangzhou
18 AUG 2016	Team Meeting 4
27 AUG 2016	Seminar
02 SEP 2016	Team Meeting 5
14 SEP 2016	Meeting 3 – Local Vehicle Dealer
22 SEP 2016	Stakeholder Engagement 1 – Non-franchised Bus Operator
27 SEP 2016	Meeting 4 – Local Vehicle Dealer & E-bus Manufacturers
30 SEP 2016	Team Meeting 6
30 SEP 2016	Stakeholder Engagement 2 – Public Light Bus Operators
06 OCT 2016	Meeting 5 – Non-franchised Bus Operator
13 OCT 2016	Public Forum
20 OCT 2016	Team Meeting 7
25 OCT 2016	Meeting 6 – Hong Kong Productivity Council
26 OCT 2016	Stakeholder Engagement 3 – Green Mobility Innovations
04 NOV 2016	Meeting 7 – Sha Tin District Council Members
16 NOV 2016	Stakeholder Engagement 4 – Public Light Bus Operators
01 DEC 2016	Stakeholder Engagement 5 – Public Omnibus Operators Association
19 DEC 2016	Meeting 8 – Steering Committee on the Promotion of Electric Vehicles

Table 2) Research Activity Objectives and Organizations Participated

Activities	Objectives	Organization
Meeting 1	To explore the current development of e-bus/ minibus in China	China Road Transport Association; Technological and Higher Education Institute of Hong Kong
Meeting 2	To discuss the technical visit arrangement to Hangzhou and explore the availability of e-bus/ minibus from a Hong Kong based manufacturer	Consolidated Parts & Accessories Sales Centre Ltd.; FDG Electric Vehicles Ltd.
Meeting 3	To explore the availability of Skywell e-minibus	Fortune Dragon Motors Ltd.
Meeting 4	To explore the readiness of e-bus/ minibus products for Hong Kong	Consolidated Parts & Accessories Sales Centre Ltd.; FDG Electric Vehicles Ltd.; Prime Motors Ltd.; Zhenzhou Yutong Bus Co. Ltd.

Meeting 5	To explore the operation mode of NFB; To collect the operation data;	Kwoon Chung Bus Holdings Ltd.
Meeting 6	To explore the local capabilities of EV related industries; To learn about the feasibilities of initial ideas for policy suggestions in HKPC's view;	Hong Kong Productivity Council
Meeting 7	To explore availability and difficulties of single-deck bus/ minibus electrification in district; To share research findings	Sha Tin District Councillors
Meeting 8	To share the researching findings; To discuss the electrification of single-deck bus and minibus in Hong Kong	Steering Committee on the Promotion of Electric Vehicles led by the Financial Secretary
Stakeholder Engagement 1	To investigate the difficulties of NFB operators in vehicle electrification; To explore the operation mode of NFB; To share the city experience in Mainland China and Europe	Kwoon Chung Bus Holdings Ltd.
Stakeholder Engagement 2	To investigate the difficulties of minibus operator in vehicle electrification; To explore the operation mode of minibus; To share the city experience in Mainland China and Europe	AMS Public Transport Holdings Ltd.; Kwoon Wing Motor Ltd.
Stakeholder Engagement 3	To explore the local capability of e-bus/ minibus manufacturer; To learn about the feasibilities of initial ideas for policy suggestions in GMI's view;	Green Mobility Innovation Ltd., Lok Wah Minibus
Stakeholder Engagement 4	To investigate the difficulties of minibus operator in vehicle electrification; To share research findings and ideas of policy suggestions	PLB operator in Shatin Sha Tin District Councillors
Stakeholder Engagement 5	To investigate the difficulties of non-franchised bus operators in vehicle electrification; To share research findings and ideas of policy suggestions	Public Omnibus Operation Association
Public Forum	To share the findings with Legco, district councillor and different organizations; To collects views on e-bus/ minibus in different perspectives;	Legislative Councillors; <u>District Councillors from:</u> Central Western; Kowloon City; Kwun Tong; North; Sai Kung; Sha Tin; Tai Po; <u>Charging Equipment Providers:</u> Smart-charge <u>Dealers/ Suppliers:</u> Consolidated Parts & Accessories Sales Centre Ltd.; FDG Electric Vehicles Ltd.; Fortune Dragon Motors Ltd.; Inchcape Motor Services Ltd.; Prime Motors Ltd.;

		Shui Cheong Motors Ltd.; Education: The Hong Kong School of Motoring; Technological and Higher Education Institute of Hong Kong; The University of Hong Kong; Green Groups: Clean Air Network; The Conservancy Association; The Green Earth; Greeners Action; WWF; Public: Hong Kong Productivity Council Ta Kung Pao (H.K.) Ltd.
Seminar	To share the findings with local stakeholders; To collect views on e-bus/ minibus in different perspectives;	Aecom Asia Argos Bus Services Co. Ltd.; Business Environmental Council Ltd.; CLP Power Hong Kong Ltd.; Environmental Protection Department; GMB Maxicab Operators General Association Ltd.; Hong Kong Airport; Hong Kong Electric Co.; Hong Kong Polytechnic University; Hong Kong Productivity Council; The Kowloon Motor Bus Co. Ltd.; New Lantao Bus Co. Ltd.; New World First Bus Services Ltd.; Park Island Transport Co. Ltd.; Public Omnibus Operation Association
Team Meeting 1	To discuss the arrangements of technical visits to China and Europe; To formalize the question set for government officers	The Team
Team Meeting 2	To formalize the presentation slides;	The Team
Team Meeting 3	To review the project progress; To plan for consultation exercise at the next stage;	The Team
Team Meeting 4	To undergo preparatory presentation for seminar on 27 Aug 2016;	The Team
Team Meeting 5	To discuss and formalize the consultation survey and proposal for the final policy suggestion	The Team
Team Meeting 6	To discuss e-bus/ minibus data collection; To discuss the arrangement of public forum	The Team
Team Meeting 7	To discuss policy options and financial implications	The Team
Technical Visit 1 – Shenzhen	To visit Build Your Dreams, Shenzhen Eastern Bus and Shenzhen Development and Reform Commission; To explore the readiness of e-buses, the	Build Your Dreams; Shenzhen Development and Reform Commission; Shenzhen Eastern Bus Co. Ltd.

	operation mode, and the policy framework	
Technical Visit 2 – Beijing & Qingdao	Beijing (23rd – 24th): To visit Ur-Car, Beiqi Foton Motor, China Public Transportation Association and State Council Research Office; To explore the readiness of e-buses, the operation mode, and the policy framework Qingdao (25th – 26th): To visit two public bus operators in Qingdao; To investigate the battery swapping system	Beijing: Beiqi Foton Motor Co. Ltd.; China Public Transportation Association; Microvast; State Council Research Office; Ur-Car Qingdao: Jowin Group; Qingdao Zhenqing Bashi
Technical Visit 3 – Chongqing	To visit Chongqing Hengtong; To investigate the first ultra-fast charging technology trial scheme in China	Chongqing Hengtong Bus Co. Ltd.
Technical Visit 4 - Zhengzhou	To visit Zhengzhou Yutong and Zhengzhou Industry and Information Technology Committee;	Zhengzhou Industry and Information Technology Committee; Zhengzhou Yutong
Technical Visit 5 – Brussels, Munster, London & Belfast	Brussels, Belgium: To visit International Association of Public Transport; To learn the e-bus development in Europe; To learn the EU funded e-bus demonstration project – ZeEUS; Munster, Germany: To visit Stadtwerke Munster; To investigate the ultra-fast charging technology in Munster; London, England: To visit Transport for London; To learn e-bus development in London; To investigate the e-bus trial schemes in London; Belfast, Northern Ireland: To visit Wrightbus; To explore the readiness of e-buses	Brussels: International Association of Public Transport; Munster: Stadtwerke Munster; VDL; London: Transport for London; Belfast: Wrightbus

Appendix B: Electric Bus and Minibus Manufacturers

Continent	Country	Manufacturer	Minibus production (1)	Contact	Website	Note
Americas	Brazil	Eletra Bus		Edmir Nogueira edmir@libris.com.br Marco Paulo marcopaulo@libris.com.br	official website	Technology behind batteries and recharge stations was designed by Mitsubishi Heavy Industries.
	United State	Environmental Performance Vehicles		The official website is not accessible	official website	
		New Flyer		**Winnipeg Headquarters** **Fax: 204-224-4214** Service department service@newflyer.com **Parts department** parts@newflyer.com	official website	
		Proterra		Email is not provided, but message can be left in the official website Service Parts Department ServiceParts@Proterra.com	official website	
		Astonbus			official website	Astonbus is a subsidiary of Zonda in China
		Smith Electric Vehicles	X	**Smith Electric Vehicles (US)** Phone: +001.816.464.0508 **Smith Technologies Ltd** Phone: +44.845.077.9077 Email is not provided, but message can be left in the official website	official website	The Smith Technologies Ltd is located in the United Kingdom
		Complete Coach Works		Email is not provided, but message can be left in the official website	official website	
		NOVA BUS		**Products and services** novabus.sales@volvo.com	official website	Nova Bus is a subsidiary of Volvo Buses in Sweden
		Ebus		sales@ebus.com	official website	
		Trans Tech Bus		sales@transtechbus.com	official website	School bus is the main

						production
		Phoenix Motorcars	X	info@phoenixmotorcars.com	official website	Shuttle bus with 12-18 seats is the main production
Asia	China	BYD		bydauto@byd.com	official website	
		Zonda		info@zonda.com	official website	
		Jingzhou Xinwei	X	dj@jzxwev.com	official website	
		Eagle EV		export@eg-ev.com	official website	
		Yangzhou Dawn		yzdawn002@vip.163.com	official website	
		Zhong Tong	X	Sales department Phone: 0635-8321076/8322624 Email is not provided, but message can be left in the official website	official website	
		Yutong Buses	X	Oversea sales sales@yutong.com Heavy industry (重工服务) zgservice@yutong.com	official website	
		Wanxiang EV	X	Pin Ni, *President* pni@wanxiang.com Gary E. Wetzel, *COO/CFO* gwetzel@wanxiang.com Michael J. Schaal, *General Manager* mschaal@wanxiang.com	official website	
		Young Man		Overseas@young-man.cn	official website	The company is a comprehensive automobile industrial group that produces and sells NEOPLAN passenger coaches
		Ankai Automobile	X	ankai@ankai.com International email address ak.jac.marketing@hotmail.com	official website	
		Shandong Yixing Electric Auto		Fax: (0539)8226316 Phone: (0635)8225546	third-party website third-party website	
		Sino EvTech		Fax: (+86) (10) 80109263 Phone: (+86) (10) 67872328	official website	
		Jiangsu Alfa Bus	X	alfabus@mgo.com.cn	third-party website third-party website	
		Guangtong Bus		linda8226609@163.com	official website	

		BonLuckBus		sales@bonluckbus.com service@bonluckbus.com htblkxs@bonluckbus.com	official website	Bonluck Bus is a subsidiary of Hengtin Group
		Sunwin	X	Fax: +86 (0)21-24160416 Phone: +86 (0)21-24160000 +86 (0)21-24160108	official website	
		YinLong	X	mail.zhyle.com	official website	
		Heng Tong Bus	X	Company office: bgs@hengtongbus.com Sales: xsgs@hengtongbus.com Technical centre: jszx@hengtongbus.com	official website	
		Higer Bus		export@higer.com	official website	
		GAC Group		webmaster@gagc.com.cn	official website	
		Ruihua group		ruihua@ruihuagroup.com.cn	Third-party website	
		Ankai		Phone: 0551-62297980 Email is not provided, but message can be left in the official website	official website	
	Japan	Mitsubishi		Email is not provided, but inquiries can be sent in the official website	official website third-party website	
	Korea	Hyundai		Email is not provided, but message can be left in the official website	official website	
		Hankuk Fiber Group		Fax: 055-353-4924	official website	
	Malaysia	Prasarna		The contact of industrial department is not provided. The contact of public bus service department: suggest@rapidkl.com.my	official website	
Europe	Belgium	Van Hool		info@vanhool.be	official website	
	Czech Republic	SOR libchavy		sor@sor.cz	official website	
		SKODA		transportation@skoda.cz	official website	
	France	Power Vehicle Innovation		info@pvi.fr	official website	

		Gruau		Email is not provided, but message can be left in the official website	official website	
		Bolloré group		Fax : +33(0)2 98 59 67 79 Contact page	official website	
	Germany	Vossloh Kiepe		info@vkd.vossloh.com	official website	
		Neoplan		phone: +49 (0)89 1580 – 01 Email is not provided, but message can be left in the official website	official website	Neoplan is a subsidiary of Man SE in Germany
	Italy	BredaMenarinibus		bredamenarinibus@bredamenarinibus.it	official website	
		TECNOBUS		Fax: 0039.0775.838751 Email is not provided, but message can be left in the official website	official website	
	Netherlands	EBUSCO		Email is not provided, but message can be left in the official website	official website	
		e-Traction		**e-Traction** info@e-traction.com **e-Traction China** info.china@e-traction.com	official website	
		Spykstaal	X	info@spijkstaal.nl	official website	
		Bluekens		Email is not provided, but message can be left in the official website	official website	Volvo Buses in Sweden is Bluekens level one service distributor
		eMoss	X	info@emoss.biz	official website	
		VDL Bus & Coach	X	info@vdlbuscoach.com	official website	
	Poland	AMZ-Kutno		fax. +48 (0) 24 357 99 01	official website third-party website (2)	
		Solaris		office@solarisbus.com	official website	
	Spain	Irizar		**recambios@irizar.com**	official website	
	Sweden	Volvo Buses		contact page	official website	There is an office in Hong Kong
	Switzerland	HESS		info@hess-ag.ch	official website	
	Ukraine	Lviv Bus Factory		The official website is not accessible	official website	
	United Kingdom	Optare		info@optare.com	official website	
		Wright Bus		Email is not provided, but message can be left in the official website	official website	
		Alexander		Email is not provided, but message can be	official website	There is an office in Hong Kong

		Dennnis		left in the official website		
Oceania	Australia	Varley Group		enquiries@varleygroup.com	official website	

1) (16 seat minibus) (X = yes) (blank = uncertain)
2) no electric bus shown in the official AMZ website, but the production of electric bus can be found in wikipedia and news

Appendix C: Observed available e-buses and e-minibuses during technical visits to China and Europe

Part Ia: China -Buses

Beijing – Foton

Model	Foton BJ6123EVCA
Length x width x height (mm)	12000 x 2550 x 3250
Energy storage at the time of visit	Lithium NMC
No. of seat (Maximum capacity)	24 – 43 (70)
Maximum velocity (km/h)	≤69
Gradeability(%)	
Battery capacity (kWh)	129

Charging

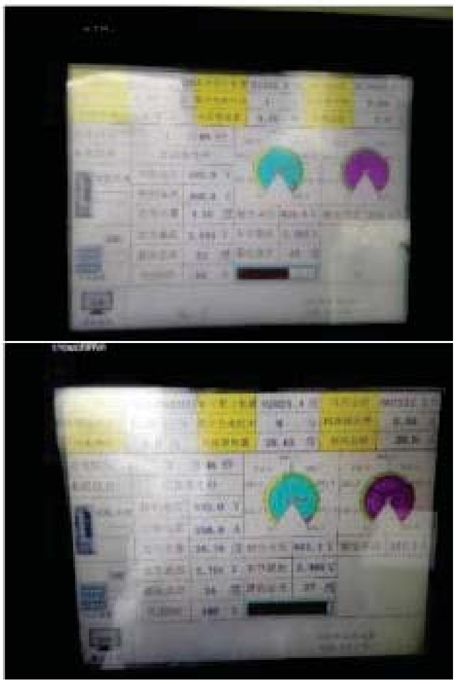
- Charging facility & service: National Grid
  - Specific staff staying at the station & operating charging stations
  - Bus drivers are not allowed to charge the bus by themselves
- 30 fast charging & 5 slow charging facilities: 100 E-buses
- Charging standard:
  - Charging current & voltage: 400A & 600V Charging time: 10mins
  - 2 charging guns operating at the same time

Chongqing – Hentong

Model	Hentong CKZ6127
Length x width x height (mm)	12000 x 2550 x 3385 (air conditioning)
Energy storage at the time of visit	Lithium Titanate
No. of seat (Maximum capacity)	45 (70)
Maximum velocity (km/h)	≥80
Gradeability(%)	≥16
Battery Capacity (kWh)	77.8

Charging

- Charging facility & service: National Grid
- Charging standard:
  - Charging current & voltage: 400A & 700V
  - Charging time: 8mins
  - 2 charging guns operating at the same time
- SOC 61% to 100%: 9mins 33sec (soc↑; current↓)



Chongqing – Hentong 8m

Model	Hentong CKZ6812HBEV
Length x width x height (mm)	8140 x 2200 x 2800
Energy storage at the time of visit	Lithium NMC
No. of seat (Maximum capacity)	25 (50)
Maximum velocity (km/h)	
Gradeability(%)	
Battery Capacity (kWh)	64.3

Charging

- Charging facility & service: National Grid
- Charging standard:
  - Charging current & voltage: 400A & 700V
  - Charging time: 13mins, 2 times charging a day
  - 2 charging guns operating at the same time

Nanjing – Skywell 8.5m

Model	Skywell NJL6859BEV
Length x width x height (mm)	8500 x 2460 x 3120
Energy storage at the time of visit	Lithium NMC/ Lithium Iron Phosphate
No. of seat (Maximum capacity)	10- 30 (66)
Maximum velocity (km/h)	69
Gradeability(%)	
Battery Capacity (kWh)	64.4/ 89.9

Charging

- Charging facility& service: Outsourced to TELD by operator
  - 6 charging ports and 2 charging guns per port serving 48 E-buses in 楊子路charging station.
  - TELD, as the tender, provide a whole package of solution to satisfy the need of E-bus operation;
- "2 guns 1 port" system has the following advantages;
  - During peak hours, E-buses can be charged by 2 guns at the same time
  - During non-peak hours or breaks, one charging gun can be inserted to one E-bus;
    - Increasing the charging time, but more E-buses can be topped up

Charging

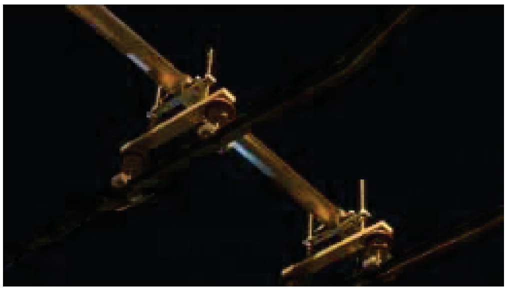
- Module charging system
- A main control centre in the charging system,
  - Showing the information of charging and battery of each charging port
  - It is believed the total cost would be lowered down, as the design of charging port is more simple

Shanghai – Sunwin

Model	Sunwin SWB6121SC
Length x width x height (mm)	12000 x 2550 x 3470
Energy storage at the time of visit	Supercapacitor
No. of seat (Maximum capacity)	35 (70)
Maximum velocity (km/h)	50
Gradeability(%)	12%
Supercap Capacity (kWh)	30

Charging

- In route 26, serval pantographs installed in each station
  - Fast charging at bus stop & termini
  - Height of pantograph: must be <4m, (limited by Shanghai government)
- Charging standard:
  - Charging current & voltage: 150~ 200A & 600v
  - Charging time: 3mins



Shenzhen – BYD

Model	BYD K9
Length x width x height (mm)	12000 x 2550 x 3360
Energy storage at the time of visit	Lithium Iron Phosphate
No. of seat (Maximum capacity)	31 (68)
Maximum velocity (km/h)	70
Gradeability(%)	≥15%
Battery Capacity (kWh)	

Charging

- Operator:
  - 38 charging station owned
  - Six hundreds more charging guns
  - The ratio of charging gun to e-bus: 1:2

Suzhou – Higer

Model	Higer KLQ6129GEV
Length x width x height (mm)	12000 x 2550 x 3150
Energy storage at the time of visit	Lithium NMC
No. of seat (Maximum capacity)	
Maximum velocity (km/h)	
Gradeability(%)	
Battery Capacity (kWh)	120

Charging

- Charging facility & service: National Grid
  - Drivers are allowed to charge e-buses
  - operation started in March 2016
- 20 charging ports serves 60 e-buses in total
- Charging standard:
  - Charging current & voltage: 260A & 600V
  - Charging time: 1 hr
  - 1 charging guns connected
- Charging guns can either be separately distributed to two E-buses at the same time
- OR both guns inserted to one E-bus for faster charging

Zhengzhou – Yutong

Model	Yutong E12
Length x width x height (mm)	12000 x 2550 x 3250
Energy storage at the time of visit	Lithium Iron Phosphate
No. of seat (Maximum capacity)	
Maximum velocity (km/h)	
Gradeability(%)	
Battery Capacity (kWh)	147/ 285

Charging

- Charging facility: Tiamaes
- Charging standard:
  - Charging current & voltage: 150A & 380V
  - Charging time: 3hrs (285kWh)
- Automatically adjusted charging power output found
  - To open the charging station to the general public
  - E-buses charging over night and private vehicles charging in daytime
- 300 charging guns installed by the operator.
  - Considering installation as a kind of investment
  - Providing charging service to the general public

Part Ib: China – Minibuses

Beijing – Foton

Model	Foton BJ6650EVCA
Length x width x height (mm)	6530 x 2230 x 2830
Energy storage at the time of visit	
No. of seat (Maximum capacity)	11 – 15 (36)
Maximum velocity (km/h)	
Gradeability(%)	
Battery Capacity (kWh)	

Hangzhou – Changjiang

- Changjiang e-minibus in production
- 3 doors
- Wheel-side Dual-motor Drive Axle
- Charging time:
  - On-board charger: 8hrs
  - Fast charging: 0.5-1hr (80% SOC)

Model	Changjiang Luxury Bus
Length x width x height (mm)	6810/ 7490/ 8310 x 2195 x 2790
Energy storage at the time of visit	Lithium Iron Phosphate
No. of seat (Maximum capacity)	10-19/ 10-22/ 10-25
Maximum velocity (km/h)	≥130
Gradeability(%)	31
Battery Capacity (kWh)	76/ 96 (7490mm)






Nanjing – Skywell

- Skywell e-minibus in production
- Charging time: 4 hrs
- Flexible seat arrangement

Model	Skywell NJL6706BEV
Length x width x height (mm)	7000 x 2050 x 2780
Energy storage at the time of visit	Lithium Iron Phosphate
No. of seat (Maximum capacity)	21 + 1
Maximum velocity (km/h)	80
Gradability(%)	≥20%
Battery Capacity (kWh)	67.8






Suzhou – Higer

Model	Higer KLQ6702EV
Length x width x height (mm)	7020 x 2040 x 2790
Energy storage at the time of visit	
No. of seat (Maximum capacity)	(22)
Maximum velocity (km/h)	
Gradability(%)	
Battery Capacity (kWh)	

Zhengzhou – Yutong

Model	Yutong E6
Length x width x height (mm)	6395 x 2065 x 2930
Energy storage at the time of visit	
No. of seat (Maximum capacity)	10 – 19 (26)
Maximum velocity (km/h)	
Gradability(%)	
Battery Capacity (kWh)	

IIa: Europe – Buses

London – BYD

Model	BYD K9
Length x width x height (mm)	12000 x 2550 x 3360
Energy storage at the time of visit	Lithium Iron Phosphate
No. of seat (Maximum capacity)	31 (68)
Maximum velocity (km/h)	70
Gradeability(%)	≥15
Battery Capacity (kWh)	324

Charging

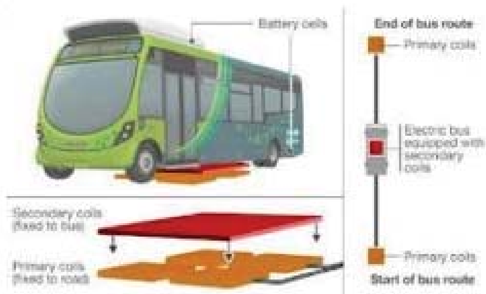
- With respect to the 2 BYD buses in trial
  - Charging current & voltage: 63A & 400V
  - Charging time: 6 ~ 8hrs
  - 4 working hours in both morning and afternoon
  - The buses start operating at 5am in the morning and be back to station at about 1 pm
  - No need of extra charging

Milton Keynes – Wrightbus

Model	Wrightbus StreetLite
Length x width x height (mm)	8780 x 2445 x 2990
Energy storage at the time of visit	Lithium ion
No. of seat (Maximum capacity)	41 (70)
Maximum velocity (km/h)	
Gradeability(%)	
Battery Capacity (kWh)	120

Charging

- Operation started: Jan 2014
- 8 Wrightbus Streetlite EV
- Route: 30km round trip (800,000 passengers per year)
- Slow charging at night (4 hours)
- Inductive charging / opportunity charging at Termini



Bbc, 2014 (http://www.bbc.com/news/technology-25621426))

Munster – VDL

Model	VDL SLF-120 Electric
Length x width x height (mm)	12000 x 2550 x 3120
Energy storage at the time of visit	Lithium Titanate
No. of seat (Maximum capacity)	(100)
Maximum velocity (km/h)	
Gradeability(%)	
Battery Capacity (kWh)	62.6

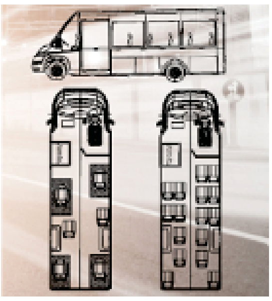
Charging

- Charging current & voltage: 500A & 625V
- The first charging system implemented at both termini, but the trial has been stopped
  - Alignment between the charging receptor on top of the bus and the charging gun on top of the bus shelter
  - Too difficult in real-life operation
- Another charging system is under construction currently. It has been changed to pantograph system

IIb: Europe – Minibuses

UK – Nu track

- Nu Track: acquired by the sole shareholder of Wrightbus Limited
  - Design and manufacture specialist vehicles including wheelchair accessible coach built buses/ minibus conversions, school buses and courtesy coaches
- City Dash
  - Low floor
  - 16 passengers or 4 wheelchairs

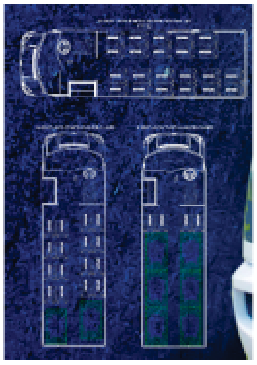


Model	Nu Track City Dash
Length x width x height (mm)	7500x 2240 x 2790
Energy storage at the time of visit	
No. of seat (Maximum capacity)	16
Maximum velocity (km/h)	
Gradeability(%)	
Battery Capacity (kWh)	

http://nu-track.co.uk/city-dash-low-floor-16-seat-bus/attachment/img_9593/
http://nu-track.co.uk/sample-page-2/

UK – Nu track

- City Lift
- 3 steps entry
- 22 passengers or 4 wheelchairs



Model	Nu Track City Lift
Length x width x height (mm)	7380 x 2260 x 2920
Energy storage at the time of visit	
No. of seat (Maximum capacity)	16
Maximum velocity (km/h)	
Gradeability(%)	
Battery Capacity (kWh)	

http://nu-track.co.uk/our-buses/city-lift-22-seat-accessible-bus/
http://www.busandcoachbuyer.com/apse-2015/

Appendix D : E-bus seminar, public forum notices and consultative document

1. Seminar on electrification of single-deck bus and minibus in Hong Kong, 27 August 2016
2. Public forum on promoting electrifying single-deck bus and minibus in Hong Kong, 13 October 2016
3. Consultation document

THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING 土木及環境工程學系

ELECTRIFICATION OF SINGLE-DECK BUS AND MINIBUS IN HONG KONG

27 August 2016 (Saturday) at 14:00 – 17:00
Room PQ303, The Hong Kong Polytechnic University (PolyU)

Programme	
13:30	**Registration**
14:00 – 14:30	**City Experiences of E-Bus and E-Minibus** *Dr. Wing-tat HUNG, Associate Professor, Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University*
14:30 – 15:00	**Battery Technologies, Advantages and Limitations** *Dr. Edward Wai-chau LO, Associate Professor and Associate Head, Department of Electrical Engineering, The Hong Kong Polytechnic University*
15:00 – 15:30	**E-Bus and E-Minibus Availability to Hong Kong** *Professor Chun-shun CHEUNG, Department of Mechanical Engineering, The Hong Kong Polytechnic University; and Mr. Kane Yuet-hung SHUM, Senior Research Fellow, Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University*
15:30 – 16:30	**Open Discussion**

Introduction

The Chief Executive has announced to introduce electric buses into Hong Kong in his 2016 Policy Address as a measure to tackle air pollution in urban areas. We are conducting a public policy research project entitled "Electrification of single-deck bus and minibus in Hong Kong" funded by the Central Policy Unit of the Hong Kong SAR Government". The main objective of this project is to substantiate government policy to introduce e-bus and e-minibus to Hong Kong. Crucial questions such as a) is battery technology feasible and practicable in bus and minibus? b) are there available e-bus and e-minibus for Hong Kong? and c) what supports from Government are needed? will be answered.

The research team has visited several cities in Mainland China and Europe to investigate the technological development and applications of these e-vehicles as well as corresponding governmental support and operators' reactions. E-buses have been aggressively promoted in China in a large scale, and gradually been introduced in many cities in Europe.

This seminar is to report the initial findings of the research team and solicit views of stakeholders on introduction of eBus and e-minibus to Hong Kong. **The seminar is presented in Cantonese.**

Speakers' Biographies

Prof. Chun-shun CHEUNG obtained his BSc degree in 1978 and his MSc degree in 1988, from the Hong Kong University. He obtained his PhD from The Hong Kong Polytechnic University in 1995. After graduating in 1978, he joined a ship management company as Assistant Engineer and left in 1985 as Marine Superintendent. He worked as a Graduate Lecturer in a technical institute before joining The Hong Kong Polytechnic University as lecturer in 1990. He is now a full Professor. Prof. Cheung has conducted various research and consultancy projects in pollutant emissions and control in relation to internal combustion engines and motor vehicles.

Dr. Wing-Tat HUNG is currently an Associate Professor in the Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University. He lectures transport infrastructure development and its environmental impacts. His research interests fall in the areas of vehicle emissions, highway noise and safety as well as large infrastructure development. In his over 20 years of academic career, Dr. Hung publishes widely in referred journals, books, conferences and local paper columns. Dr. Hung is also active in many professional bodies, including the Chartered Institute of Logistics and Transport and Board member of the Hong Kong Society for Transportation Studies as well as the environmental group Conservancy Association. He was also expert advisors to the Hong Kong 2030 Study and the Planning Study on the co-ordinated development of the Greater Pearl River Delta townships. He is currently a member of the Advisory Council on the Environment. He involved in many Government projects on vehicle emission control including a) alternative fuels for taxi and minibuses; b) low cost after-treatment devices for small diesel vehicles; c) diesel catalyst for heavy duty diesel vehicles and d) the pilot transport green fund projects.

Dr. Edward Wai-chau LO received his Higher Diploma award in Electronic Engineering from Hong Kong Polytechnic, and then he obtained his BSc(Eng) (First Class Honor), MPhil, and PhD degrees, all from the Department of Electrical Engineering in The University of Hong Kong. In January 2000, Dr. Lo joined the Department of Electrical Engineering at The Hong Kong Polytechnic University. Now he is the Associate Head and an Associate Professor of the Department. Before joining the Department, Dr. Lo worked, on and off, for a number of tertiary institutes in Hong Kong and accumulated 10 years of teaching experience. In between, he worked as a R&D Engineer in a private electronic firm for a year (1983-84), he was a visiting scholar in University of Tokyo for a year (1987-88), and he also served as a Professional Scientist in the Device and Energy Section of the Telecom Research Laboratory of Telecom Australia for three years (1991-93). Currently, Dr. Lo's main areas of research interests are renewable energy, electrical services of buildings, building automation systems, power quality, and power electronics, drives and traction. In recent years, he has undertaken a number of consultancy projects for the Airport Authority (Hong Kong), railway corporations, HKSAR Government, Macau SAR Government and other private firms. Dr. Lo has been a member of the Grade C Licensing Examination Committee for electrical workers since 1996. Dr. Lo is a Member of Hong Kong Institution of Engineers (HKIE). He also serves in a number of committees in HKIE and departments of HKSAR Government.

Mr. Kane Yuet-hung Shum has been the Engineering Manager/Principal Engineer, Bus Engineering of The Kowloon Motor Bus Co (1933) Ltd (KMB) for 17 years and has been responsible for overseeing all aspects related to bus engineering. He has been heavily involved in improving exhaust emission in buses including the test and installation program of oxidation catalysts in more than 2,600 pre-Euro and Euro I engined buses, the introduction of ultra-low sulphur diesel (ULSD) and Near Zero Sulphur Diesel (NZSD) for the whole KMB bus fleet, the test of Diesel Particulate Filter (DPF) and a program to install more than 1,600 Euro II and Euro III engined buses as well as many other programs including the introduction of Euro IV and Euro V engined buses to Hong Kong to improve bus exhaust emissions. He has also been working with manufacturers on the improvement measures of the drive-line and air-conditioning system efficiency for buses and has established a proactive maintenance system in KMB. He has introduced the supercapacitor bus and pure electric bus for trial in Hong Kong from 2010 to 2013 and have been arranging the purchasing of the supercapacitor bus and pure electric bus for the pilot program in KMB. He has also introduced the Double Deck 12 metre hybrid buses for trial in Hong Kong in 2014.

Registration

Free of charge to attend the seminar. Please fill in the following registration form and return to:

Dr. HUNG Wing Tat, Department of Civil and Environmental, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR.
Tel: (852) 2766-6044, Fax: (852) 2334-6389, E-mail: cewthung@polyu.edu.hk.

Title:	Prof. /Dr. / Mr./ Miss / Ms.
Name:	
Affiliation and Position:	
Tel:	
Email:	

THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING 土木及環境工程學系

推動香港單層巴士及小巴電動化的公眾論壇

2016 年 **10** 月 **13** 日**(**四**)** 下午 **14:00 – 17:30**

香港理工大　**M1603** 室

議程	
13:30	報名登記
14:00 – 14:20	純電動巴士和小巴的城市經驗 *香港理工大學土木及環境工程學系副教授熊永達博士*
14:20 – 14:40	電池技術，優勢與局限 *香港理工大學電機工程學系副系主任勞偉籌博士*
14:40 – 15:00	純電動巴士和小巴在香港的適用性 *香港理工大學機械工程學系教授張鎮順博士；和* *香港理工大學土木及環境工程學系高級研究員及前九巴首席機械工程師沈乙紅先生*
15:00 – 16:30	評論員回應及公開討論

研討會介紹

想知道香港能成為全電動公交的環保城市嗎?

這論壇提供平台，請您一齊參與，尋找答案。

中央政策組資作理大環境及土木工程　系研究項目

報名登記

是次公眾論壇會以廣東話進行。
座位有限，先到先得。成功登記，會在一星期內通知。請登入以下網址登記。

https://goo.gl/forms/zFAntlvj2vhen6Lf1

(如遇上問題，請更新網絡瀏覽器後再次嘗試。)
如有其他疑問，請聯絡許熙彤先生。電郵地址： hei.hui@polyu.edu.hk

單層巴士及小巴電動化

諮詢文件

研究團隊:

熊永達(土木及環境工程學系)

張鎮順(機械工程學系)

勞偉籌(電機工程學系)

沈乙紅(土木及環境工程學系)

許熙彤(土木及環境工程學系)

2016 年 8 月

The Hong Kong Polytechnic University
香港理工大學

中央政策組公共政策研究資助計劃資助

引言

行政長官在 2016 年的施政報告中，宣佈引入純電動巴士，以減輕市區空氣污染。為回應這項政策建議，我們正在進行一項由香港特區政府中央政策組資助的研究項目："推動香港單層巴士及小巴電動化的研究"。主要目的是要回答幾個關鍵問題：A）現時電池技術在單層巴士及小巴上是否實際可行？B）是否有香港可用的純電動巴士和小巴？和 C）政府需要提供怎樣的支援？

研究小組走訪了中國大陸和歐洲的多個城市，調查純電動巴士的技術開發和應用，以及相關政府的支持和運營商的看法和反應。

這份文件匯集了本研究的初步結果，並包含一份問卷，搜集業界對香港引進純電動巴士和小巴的基本看法。

1. 電動巴士/小巴普及情況

隨著愈來愈多製造商投入公共交通電動車市場，電動巴士/小巴技術和質量得到長足進步，展現出有能力改善城市空氣質素。與此同時，各國政府相繼推出政策，試驗和推廣計劃，配合電動巴士/小巴的普及發展。同時帶動整個電巴工業發展，催生新式產業和服務模式，如外判充電設備和服務。

政府在電動車發展上擔當無可取代的角色。尤其是公共交通電動化上，缺乏政府主導和政策配合將會非常困難，而每個界別應該擔當甚麼角色? 在不同地方也不盡相同。電動巴士在內地發展迅速，營運模式多元化，個別製造商更能夠開拓東南亞和外國市場。歐美國家支持推動電動巴士較審慎，但支持力度越來越大，許多推廣計劃正在進行中。

香港擁有天然條件推動使用電動巴士/小巴。但跟其他地方最大的不同是，公共交通是以商業/私人營運。2010年，政府宣佈全港使用零排放巴士為目標，並資助專營巴士公司試行混合動力和電動巴士，2011年，更進一步撥款成立「綠色運輸試驗基金」，資助運輸業界，採用綠色創新技術，電巴是受資助的項目之一。

北京懷柔區小營充電站。30 支快充和 5 支慢充設備服務 100 輛電巴。

2. 純電動巴士和小巴的城市經驗

城市經驗由利益相關者發揮關键角色，再加上恰當政策而構成。在每個城市當中的利益相關者都大同小異，但能形成不同的發展模式，與政府政策和支持力度息息相關。以下作簡略介紹。

2.1. 利益相關者及其角色

只有多方合作，電巴的廣泛使用，才有成功的機會。

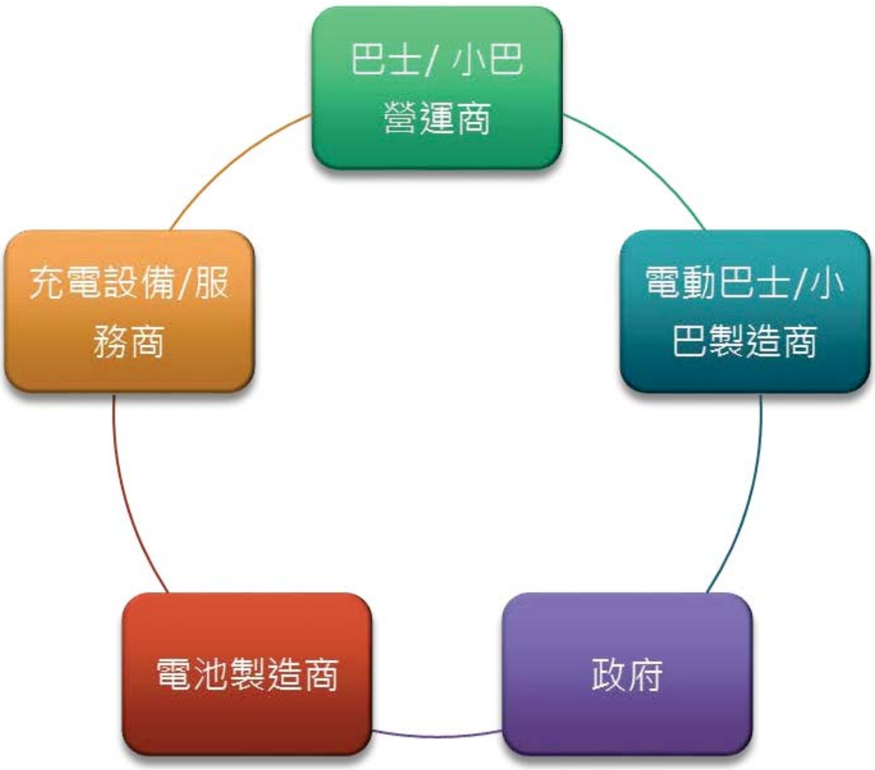
- 政府 – 主導電巴計劃，提供政策和財政支持
- 巴士/小巴營運商 – 與電動巴士/小巴製造商緊密合作去發展符合營運要求的車型
- 電動巴士/小巴製造商 – 與電池製造商和充電設備/服務商探討合作以提供解決方案
- 電池製造商 – 確保電池的能力有足夠續航力和達到 4 年或以上的壽命
- 充電設備/服務商 – 確保充電設備 配和運作正常

2.2. 現行主要政策

現時主要的政策，重點在降低電動巴士/小巴購置和營運成本。

1. 購置補貼
2. 營運補貼
3. 電動巴士/小巴稅務優惠

圖 1：關鍵的利益相關者



2.2.1. 購置補貼

中國大陸的購置補貼:

以下內容節錄自: *《關於 2016-2020 年新能源汽車推廣應用財政支持政策的通知》*財建[2015]134 號

具體的補助對象、產品和標準是：

1. 補助對象。補助對像是消費者。新能源汽車生產企業在銷售新能源汽車產品時按照扣減補助後的價格售與消費者，中央財政按程序將企業墊付的補助資金再撥付給生產企業。
2. 補助產品。中央財政補助的產品是納入“新能源汽車推廣應用工程推薦車型目錄”（以下簡稱“推薦車型目錄”）的純電動汽車、插電式混合動力汽車和燃料電池汽車。
3. 補助標準。補助標準主要依據節能減排效果，並綜合考慮生產成本、規模效應、技術進步等因素逐步退坡。 2016 年各類新能源汽車補助標準見下圖 2。2017 - 2020 年除燃料電池汽車外其他車型補助標準適當退坡，其中：2017 - 2018 年補助標准在 2016 年基礎上下降 20%，2019 - 2020 年補助標准在 2016 年基礎上下降 40%。

圖 2：中國純電動、插電式混合動力等客車推廣應用補助標準（單位：萬元/輛）

車輛類型	單位載質量能量消耗量（E_{kg}，Wh/km·kg）	標準車（10 米＜車長≤12 米）					
		純電動續駛里程 R（等速法、公里）					
		6≤R＜20	20≤R＜50	50≤R＜100	100≤R＜150	150≤R＜250	R≥250
純電動客車	E_{kg}<0.25	22	26	30	35	42	50
	0.25≤E_{kg}<0.35	20	24	28	32	38	46
	0.35≤E_{kg}<0.5	18	22	24	28	34	42
	0.5≤E_{kg}<0.6	16	18	20	25	30	36
	0.6≤E_{kg}<0.7	12	14	16	20	24	30
插電式混合動力客車（含增程式）		/	/	20	23	25	

節錄自: http://jjs.mof.gov.cn/zhengwuxinxi/zhengcefagui/201504/t20150429_1224515.html

西班牙對新能源汽車購置補貼的政策：

圖 3：由 IDEA 和西班牙地區政府提供的混合動力汽車和電動汽車的 2011 購置補貼

車輛類型（私營和工業）	混合動力及電動汽車的補貼（適用於公共部門和私營界別）
摩托車	4kW 以上摩托車最高為€750
客車(M1), 商用車(N1),和四輪車(L7e)	市場價格的 15%，最多不超過€7000
混合動力	2011 年用純電動驅動和每千米少於 110 克二氧化碳的混合動力車: 最高€2300 元; 以及不是純電動驅動的混合動力車: 最高€2,000
PHEV 和 BEV	最高€7,000；但 PHEV 的電動驅動里程最少要達到 20 公里
公交車和卡車	市場價格的 15%，最多不超過€50,000

節錄自:

http://www.ieahev.org/by-country/spain-policy-and-legislation

德國蒙斯特 VDL 電巴。歐洲正緩步推行公共電巴。

2.2.2. 營運補貼

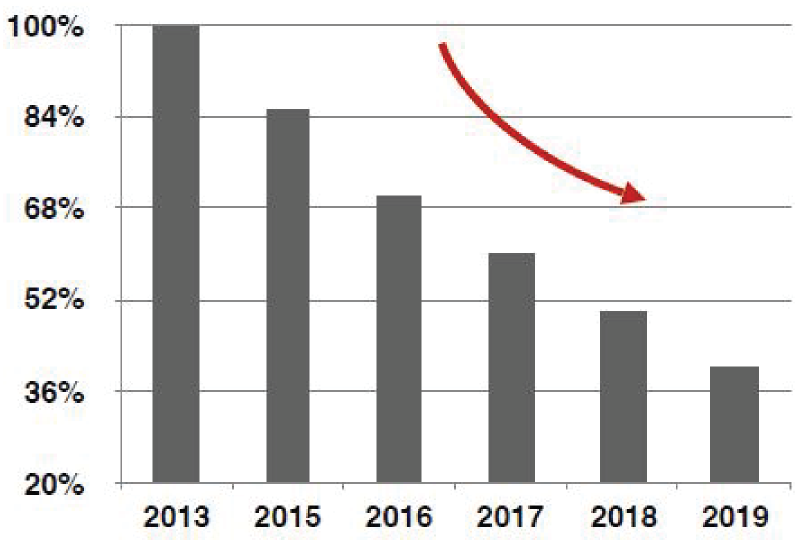
中國大陸對公交車油價補助和推廣電動巴士營運的政策：

以下內容節錄自：*《關於完善城市公交車成品油價格補助政策加快新能源汽車推廣應用的通知》*財建[2015]159 號

- 調低現行城市公交車成品油價格補貼
  - 現行城市公交車成品油價格補助中的費改稅補助作為基數保留，不作調整。 2015－2019 年，費改稅補助數額以 2013 年實際執行數作為基數予以保留，暫不做調整
  - 現行城市公交車成品油價格補助中的漲價補助以 2013 年作基數，逐年調整（圖 4）見。 2015－2019 年，現行城市公交車成品油價格補助中的漲價補助以 2013 年實際執行數作為基數**逐步遞減**，其中 2015 年減少 15%、2016 年減少 30%、2017 年減少 40%、2018 年減少 50%、2019 年減少 60%，2020 年以後根據城市公交車用能結構情況另行確定
- 漲價補助數額與新能源公交車推廣數量掛鉤
  - 2015-2019 年，城市公交車成品油價格補助中的漲價補助數額與新能源公交車推廣數量掛鉤
- 調整後的城市公交車成品油價格補助資金由地方統籌使用。
  - 調整後的城市公交車成品油價格補助資金由地方統籌用於城市公交車補助。各省（區、市）財政、工業和信息化、交通運輸等部門根據本地實際制定具體管理辦法。城市公交車補助由地方政府通過增加財政補助、調整運價等方式予以解決，確保公交行業穩定
- 中央財政對完成新能源公交車推廣目標的地區給予新能源公交車運營補助。
  - 為加快新能源公交車替換燃油公交車步伐，2015-2019 年期間中央財政對達到新能源公交車推廣目標的省份，對納入工業和信息化部 "新能源汽車推廣應用工程推薦車型目錄" 、年運營里程不低於 3 萬公里的新能源公交車以及非插電式混合動力公交車，按照其實際推廣數量給予運營補助（圖 5）。2020 年以後再綜合考慮產業發展、成本變化及優惠電價等因素調整運營補助政策

上海申沃超級電容公交。超越電容巴士的補貼在大　比一般電巴

圖 4：調整現 □ 行公交□車成品
□ 量掛鉤，漲價補貼以 2013 年實際執 □ 行數為基數逐步遞減



節錄自：香港城市新能源公交发展 (胡剑平，n.d.)

圖 5：節能與新能源公交車運營補助標準(2015-2019) (單位：萬元/輛/年)

車輛類型	車長 L（米）		
	6≤L < 8	8≤L < 10	L≥10
純電動公交車	4	6	8
插電式混合動力（含增程式）公交車	2	3	4
燃料電池公交車		6	
超級電容公交車		2	
非插電式混合動力公交車		2	

節錄自：http://www.gov.cn/xinwen/2015-05/22/content_2866789.htm

2.2.3. 電動巴士/小巴稅務優惠

中國大陸對新能源汽車購置稅的政策：

以下內容節錄自: *《關於免徵新能源汽車車輛購置稅的公告》*公告[2014]53 號

- 自 2014 年 9 月 1 日至 2017 年 12 月 31 日，對新能源汽車免徵車輛購置稅
- 對免徵車輛購置稅的新能源汽車，由工業和信息化部、國家稅務總局通過發布《免徵車輛購置稅的新能源汽車車型目錄》（以下簡稱《目錄》）實施管理
- 列入《目錄》的新能源汽車須同時符合以下條件：
  1. 獲得許可在中國境內銷售的純電動汽車、插電式（含增程式）混合動力汽車、燃料電池汽車
  2. 使用的動力電池不包括鉛酸電池
  3. 純電動續駛里程序符合《新能源汽車純電動續駛里程要求》（圖 6）
  4. 插電式混合動力乘用車綜合燃料消耗量（不含電能轉化的燃料消耗量）與現行的常規燃料消耗量國家標準中對應目標值相比小於 60%；插電式混合動力商用車綜合燃料消耗量（不含電能轉化的燃料消耗量）與現行的常規燃料消耗量國家標準中對應限值相比小於 60%
  5. 通過新能源汽車專項檢測，符合新能源汽車標準要求。《新能源汽車產品專項檢驗標準目錄》

圖 6：新能源汽車純電動續駛里程要求 (單位：km)

類別	乘用車	客車	貨車	專用車	測試方法
純電動	≥80	≥150	≥80	≥80	M1、N1 類採用工況法，其他暫採用 40km/h 等速法。
插電式（含增程式）混合動力	≥50（工況法） ≥70（等速法）	≥50	≥50	≥50	M1、N1 類採用工況法或 60km/h 等速法，其他暫採用 40km/h 等速法。
燃料電池	≥150	≥150	≥200	≥200	M1、N1 類採用工況法，其他暫採用 40km/h 等速法。

注：

1. 超級電容、鈦酸鋰快充純電動客車無純電動續駛里程要求
2. M1 類是指包括駕駛員座位在內，座位數不超過九座的載客車輛 。N1 類是指最大設計總質量不超過 3500kg 的載貨車輛

節錄自: http://www.chinatax.gov.cn/n810341/n810755/c1150779/content.html

圖 7：日本對新能源汽車購置稅的政策

Tonnage & Acquisition Tax Cuts for Eco-Friendly Vehicles

Effective Period: For the vehicle Tonnage Tax: 1 April 2009-30 April 2012
For the vehicle Acquisition Tax: 1 April 2009-31 March 2012

	Next-Generation Vehicles	Low-Emission and Fuel-Efficient Vehicles(Passenger cars and mini-vehicles)		Heavy-Duty Vehicles (Trucks and buses with GVW 3.5 tons)	
	Electric (including fuel cell) vehicles Plug-in hybrid vehicles Clean diesel vehicles Hybrid vehicles Natural gas vehicles	Emissions down by 75% from 2005 standards and Fuel efficiency 25% above 2010 standards	Emissions down by 75% from 2005 standards and Fuel efficiency 25% above 2010 standards	Compliant with 2009 emission standards and Compliant with 2015 fuel efficiency standards	Emissions down by 75% from 2005 standards and Compliant with 2015 fuel efficiency standards
Tonnage Tax	Exempt	75% reduction	50% reduction	75% reduction	50% reduction
Acquisition Tax(new vehicles only)	Exempt	75% reduction	50% reduction	75% reduction	50% reduction

節錄自 http://www.jama-english.jp/asia/news/2009/vol36/

URL:

http://www.mlit.go.jp/jidosha/jidosha_fr1_000028.html

http://www.wri.org/sites/default/files/wri_workingpaper_japan_final_ck_6_11_14.pdf

2.3. 城市經驗

2.3.1. 深圳

- 深圳市政府目標
  - 2017 -- 全市使用電動巴士
  - 2018 -- 全市使用電動的士和 50%的私家車是電動車
- 深圳市政府是最大的電動交通驅動者
  - 快充適合於公共交通，而慢充適合於私家車
  - 電動車製造商的業績是市政府的規劃一部份
  - 大力支持本地營運商使用電動巴士
- 直至 2016 三月初，深圳市政府為電動車推廣和發展總共花了 80 億人民幣
- 從 2009 開始，深圳市政府每年投入 5 億人民幣發展電動巴士。一輛 12 米電動巴士可得到中央政府獲得購置補貼 50 萬人民幣。深圳市政府的購置補貼額跟中央政府看齊。購置補貼最多只可以達到 60%，公交運營商會以抵押給銀行來購置電動巴士。而在營運補貼方面，單輛電動巴士只要能一年行駛滿 6 萬公里，在深圳最多能獲得 45 萬人民幣
- 深圳市政府正在興建 13 座電動巴士充電站，6 層地面地底各 3 層。預計 2020 年將會有 26 座，目標是每輛電動巴士均配有一支充電槍
- 東部公交(深圳市公交營運商)：
  - 營運電動巴士的得益比傳統巴士更大
  - 受益於電子化信息系統，改善巴士調度和監控的能力
- 比亞迪(本地製造商)
  - 受益於政府的補貼政策
  - 從真實營運中的電動巴士收集第一手資料，針對性改良設計

2.3.2. 重慶

在本地市政府未有大力增加電動巴士補貼金額的情況下，本地製造商積極與電池生產商緊密合作 。

- 重慶恆通 Chongqing Hentong(本地製造商)
  - 製造快充電動巴士
  - 監控電巴在工作環境下的運作
- 微宏 Microvast (電池生產商)
  - 生產特快充的電池
  - 技術支援
  - 從真實營運的電動巴士收集第一手電池的資料，改良設計

2.3.3. 南京

- 南京公交營運商
  - 將電動巴士充電外判給充電設備/服務商，由充電設備/服務商提供電動巴士充電方案滿足營運需要，並且提供日常充電服務。
  - 受益於電子化信息和管理系統，增強車輛調度和監控能力
- 特來電 TELD (充電設備/服務商)
  - 提供電動巴士充電方案滿足營運需要
  - 從營運中的充電樁收集資料，改良設計及服務
- 南京金龍 Skywell (本地製造商) 和 微宏 Microvast
  - 提供技術支援
  - 從真實營運中的電動巴士收集第一手資料，改良設計和生產

2.3.4. 倫敦

- 倫敦市政府目標：
  - 2025 年，以 1990 年二氧化碳濃度為基準，減少 60%
  - 氮氧化物將會是下一個減排目標
- 電動巴士被視為減排的有效工具。氮氧化物是倫敦市內主要的空氣污染，巴士排放氮氧化物佔交通領域裏的 28%。倫敦市政府把市內特定區域的排放標準不斷收緊(Ultra Low Emission Zones -- ULEZ)，令營運商不斷　善旗下車隊尾氣排放。2020 年，在 ULEZ 裏所有單層巴士將會是零排放，而所有雙層巴士將會是歐六標準。為了實現這個目標，倫敦市政府正大力推廣電動巴士的使用。
- Transport for London (政府部門)
  - 對所有技術持開放態度:-無線充電，混合動力，快充慢充等
- 不同的電動巴士製造商
  - 提供不同的方案來滿足 TFL 的要求
  - 例如：比亞迪(BYD) 和 ADL 合作製造電動巴士
- SSE (充電設備/服務商) 和 UK POWER (電力公　)
  - 商討合作

3. 電池技術，優勢與局限

3.1. 電力儲存模式

電池和超級電容是最可行的技術。在電動巴士，鋰電池正逐漸成為最普遍的電池。不同的鋰電化學組合也有不同的特性。鋰

電池和超級電容都能夠在高電流下充電和放電。這點很適合用在電動巴士上。詳情請見下圖 8。

3.2. 充電模式的優缺點

充電模式基本上能分為五大類，分別在基礎設施和能量儲存載體上，有不同的要求。不同的營運模式（工時、路程）和城市特色（土地、基礎建設）適合不同的充電模式。詳情請見下圖 9。

南京楊子公交星火路充電站。巴士營運商外判充電服務給特來電。

杭州長江 EV 車廠。電小巴被選用在杭州 G20 峰會。

圖 8：各類型電池的比對

電池種類/超級電容	錳酸鋰 (Lithium Manganese Oxide)	三元復合鋰 (Lithium Nickel Manganese Cobalt Oxide)	磷酸鐵鋰 (Lithium Iron Phosphate)	三元復合鋰 (Lithium Nickel Cobalt Aluminum Oxide)	鈦酸鋰 (Lithium Titanate)	超級電容 (supercapacitor)
電壓	公稱 3.70V (3.80V)； 一般工作範圍 3.0-4.2V/電池	公稱 3.60V, 3.70V；一般工作範圍 3.0-4.2V/電池，或更高	公稱 3.20, 3.30V；一般工作範圍 2.5-3.65V/電池	公稱 3.60V；一般工作範圍 3.0-4.2V/電池	公稱 2.40V; 一般工作範圍 1.8-2.85V/電池	公稱 2.40V； 一般工作範圍 1.0-2.8V/電池
能量密度 (容量)	100-150Wh/kg	150-220Wh/kg	90-120Wh/kg	200-260Wh/kg	70-80Wh/kg	一般 5Wh/kg 它與電池相比偏低
充電速度 (C-rate)	一般 0.7-1C, 最大 3C，充電 4.20V (大部分電池)	0.7-4C，充電 4.20V，部分充電 4.30V； 一般充電 3 小時。 充電電流大於 1C 可能縮短電池壽命。	一般 1C, 充電 3.65V; 一般充電 3 小時。	0.7C, 充電 4.20V (絕大部分電池); 一般充電 3 小時。某些電池能夠快充。	可行 6C	3C
放電速度 (C-rate)	1C；某些電池可行 10C，脈衝 30C pulse (5s) ，2.50V 隔斷	1C；某些電池可行 2C; 2.50V 隔斷	1C, 某些電池可行 25C; 脈衝 40A (2s); 2.50V 隔斷(低於 2V 對電池帶來傷害)	一般 1C; 3.00V 隔斷; 高放電率對電池壽命帶來傷害	可行 10C, 脈衝 30C (5s); 在 LCO/LTO 1.80V 隔斷	
循環壽命	~300-700 (跟放電深度和溫度有關)	~1,000-10,000 (跟放電深度和溫度有關)	~1,000-2000 (跟放電深度和溫度有關)	~500-1,000 (跟放電深度和溫度有關)	~5,000-20,000	~4,000-50,000
熱失控	一般 250°C (482°F)。高電荷可引起熱失控	一般 210°C (410°F)。高電荷可引起熱失控	270°C (518°F) 即使完全充電也非常安全的電池	一般 150°C (302°F), 高電荷可引起熱失控	其中一種最安全的鋰電池	內阻低，高電流操作過程中，因此產生相對少熱量，從而安全
用途	電動工具，醫療設備，電動動力系統	電動單車, 醫療設備, 電動車, 工業用途	需要高負載電流和續航力的便攜式和固定式裝備	醫療設備, 工業用途, 電動動力系統(Tesla)	UPS, 電動動力系統 (Mitsubishi i-MiEV, Honda Fit EV), 太陽能供電的路燈	UPS, 動態電壓恢復器, 大廈負載均衡系統
評論	高功率但容量較小;比鋰鈷電池更安全;通常與 NMC 混合以提高性能。	提供高容量和高功率。作為混能電池。化學上多種用途;市場份額不斷增加。	非常平坦的電壓放電曲線，但低容量。其中一個最安全的鋰離子。	跟 Li-Co 非常相似. 態作為能源電池.	壽命長，可快速充電，使用溫度範圍廣，但較低的能量比和昂貴。其中一種最安全的鋰電池	超級壽命長，非常快速充電，操作並沒有太大取決於溫度，因此工作溫度範圍寬。但非常低的比能和昂貴。

圖 9：**各類型**充電模式的比對

模式		超快充模式	快充模式	慢充模式	快換模式	在線充電模式
定義		在電動巴士營運過程中，能量補充採用停車補給，電池不脫離車體的充電方式，充電倍率最少為 6C	在電動巴士營運過程中，能量補充採用停車補給，電池不脫離車體的充電方式，充電倍率大於 1C	在電動巴士營運過程中，能量補充採用停車補給，電池不脫離車體的充電方式，充電倍率小于 0.5C	在電動巴士營運過程中，能量補充採用停車補給，電池脫離車體的充電方式，在專用場地利用設備對電池進行更換	在電動巴士營運過程中，能量補充是在行駛過程中依靠電網即時補充，離網運行時依靠電池電力，並能利用電網對電池充電
使用特點	充電方式	給車輛整體充電	給車輛整體充電	給車輛整體充電	動力電池組與車輛分離充電，更換電池組的方式補電	利用電纜實行在线行駛，又能同時充電
	充電設備	最少 6C 電流充電樁	大過 2C 電流充電樁	0.5C 以內電流充電樁	專用換電站設備	專用電纜
	時間	一般需時 10~15 分鐘左右充	一般 0.5-2 小時左右充	一般 4-8 小時可充滿	一般需時 8-15 分鐘	運行和充電同時進行
	續航里程	平均每 50km 充一次充電	平均每 60km 充一次充電	平均每 100km 充一次充電	平均每 100km 充一次充電	離線情況下利用動力電池纯電驅動
	適用環境	適用於站頭充電	單程距離適中	車輛出車密度高，運行時段無充電條件	單程車程長	有電纜、有無軌電車的城市
能量儲存類型例子		多元復合鋰, 鈦酸鋰	多元復合鋰，鈦酸鋰	磷酸鐵鋰		超級電容
	應用地方	北京，重慶，南京，蒙斯特	蘇州	深圳，倫敦，鄭州，台灣	青島, 鄭州	上海
優劣對比	優點	一個充電樁可以滿足 10 輛左右車輛輪流充電，但需要電池壽命長		充電槍數量與電動巴士數量相當	快速換電，可使電動巴士持續運行，電池的充電環境一定符合電池要求	電纜屬於一次性投資，可綜合規劃附近線路，可持續使用
	缺點	需要白天的時間來充電，對電網有一定影響	需要白天的時間來充電，對電網有一定影響	為滿足巴士單日行駛 250km 左右續駛里程，需搭載超過 300kwh 的電量，這導致車重增加和首次購置成本高，電池壽命較短	設施需要建設佔地較大的大型換電站，適用的電池箱及快速電池更換的機械設備，需配置電動巴士數量 1.4 倍以上的電池組。電池壽命較短，匹套設施建設週期長，綜合使用成本最高	電纜對市容美觀有一定影響，使用範圍有一定局限性，基礎設施的規劃和建設週期較長

4. 純電動巴士和小巴在香港的適用性

4.1. 研究小組探訪過的中國大陸和歐洲純電動巴士

車型	北京福田 BJ6123EVCA	重慶恆通 CKZ6127	重慶恆通 CKZ6812HBEV	鄭州宇通 E12	蘇州金龍 KLQ6129GEV	南京金龍 NJL6859BEV	南京金龍 NJL6121	上海申沃 SWB6121SC	比亞迪 K9	Wrightbus New Routemaster	Wrightbus StreetLite	VDL SLF-120 Electric
外部尺寸 (mm)	12000 x 2550 x 3250	12000 x 2550 x 3385	8140 x 2200 x 2800	12000 x 2550 x 3250	12000 x 2550 x 3150	8500 x 2460 x 3120	12000 x 2500 x 3150	12000 x 2550 x 3470	12000 x 2550 x 3530	11232 x 2520 x 4420	8780 x 2445 x 2990	12000 x 2550 x 3120
正在使用中的能量儲存類型	多元復合鋰	鈦酸鋰	多元復合鋰	磷酸鐵鋰	多元復合鋰	多元復合鋰 /磷酸鐵鋰		超級電容	磷酸鐵鋰	磷酸鐵鋰	鋰電池	鈦酸鋰
座位數(最大乘客人數)	24–43 (70)	45 (70)	25 (50)			10-30 (66)	(72)	35 (70)	31 (68)	62 (87)	41 (70)	(100)
最大速度 (km/h)	≤69	≥80				69		70	70			
爬坡度(%)		≥16						12	≥15			
電量(kWh)	129	77.8	64.3	147/ 285	120	64.4/ 89.9	186.5	11	324	18	120	62.5
充電時間(分鐘)	10	8	13	180 (285kWh)	60	/ 180	180	3	360 ~ 480		240	8 - 15
探訪的地方	北京	重慶	重慶	鄭州	蘇州	南京	南京(會送交馬來西亞)	上海	倫敦，深圳	倫敦	米爾頓凱恩斯	蒙斯特

4.2. 研究小組探訪過的中國大陸和歐洲純電動小巴

車型	北京福田 BJ6650EVCA	南京金龍 NJL6706BEV	長江汽車 豪華中巴	蘇州金龍 KLQ6702EV	鄭州宇通 E6	Nu Track City Dash	Nu Track City Lift
外部尺寸(mm)	6530 x 2230 x 2830	7000 x 2050 x 2780	6810/ 7490/ 8310 x 2195 x 2790	7020 x 2040 x 2790	6395 x 2065 x 2930	7500x 2240 x 2790	7380 x 2260 x 2920
正在使用中的電池類型		磷酸鐵鋰	磷酸鐵鋰				
座位數(最大乘客人數)	11 – 15 (36)	21	10-19/ 10-22/ 10-25	(22)	10 – 19 (26)	16	16
最大速度(km/h)		80	≥130				
爬坡度(%)		≥20%	31				
電量(kWh)		67.8	76 (6810mm)/ 96 (7490mm)				
充電時間(分鐘)		240	車載充電: 360/ 480 快充: 60				
探訪的地方	北京	南京	杭州	蘇州	鄭州	貝爾法斯特	貝爾法斯特

推動香港單層巴士及小巴電動化的研究
第一輪問卷調查
（2016年8月）

簡介：
本問卷調查為「推動香港單層巴士及小巴電動化的研究」項目研究的一部份，旨在就推動單層巴士及小巴電動化的各個主要方面，蒐集各界別的相關意見。

被訪者界別:

請問閣下是來自以下那個界別： ☐

1. ☐專營巴士營運商	2. ☐非專營巴士營運商	3. ☐小巴營運商
4. ☐其他小型巴士營運商	5. ☐政府部門	6. ☐電力公司
7. ☐學者	8. ☐其他 ________________	

主問卷部份

A. 充電安排方面

A1. 請您就單層電動巴士/小巴的充電安排，對下列各方面的重要性按 1~4 次序排列：**(1 為最重要)**

- ☐ 充電時間
- ☐ 充電價格
- ☐ 電池壽命/耐用情況
- ☐ 充電方便程度（例如：充電站地點、數量等）

A2. 您認為就單層巴士電動化而言，較適合以下列那種方式為主要發展方向？（**請按 1~4 次序排列，1 為最適合**）

- ☐ 方式一：過夜充電 + 日間充電 1 次
- ☐ 方式二：日間多次快速充電
- ☐ 方式三：替換電池（一至三次）
- ☐ 方式四：超級電容 (日間多次快速充電)

A3. 您認為就小巴電動化而言，較適合以下列那種方式為主要發展方向？（**請按 1~4 次序排列，1 為最適合**）

- ☐ 方式一：過夜充電 + 日間充電 1 次
- ☐ 方式二：日間多次快速充電
- ☐ 方式三：替換電池（一至三次）
- ☐ 方式四：超級電容 (日間多次快速充電)

B. 整體成本安排方面

B1. 就以下推動單層巴士及小巴電動化的整體成本安排方面，對以下個別成本項目的重要性**按 1~4 次序排列：（1 為最重要）**

☐ 電動車輛成本	☐ 更換電池成本
☐ 安裝變壓站（火牛房）	☐ 電動車充電裝置

B2. 您認為各個成本項目分別應該由下列那個/那些界別承擔/分擔？（**1.電動車供應商；2.電池供應商；3. 充電設施供應商；4.政府部門；5.巴士/小巴營運商）**
（請把各界別按次序排列，排最先為最應該承擔或分擔較多成本）

	各界別承擔/分擔成本的次序
B2a. 電動車輛成本	☐☐☐☐☐
B2b. 更換電池成本	☐☐☐☐☐
B2c. 安裝變壓站（火牛房）	☐☐☐☐☐
B2d. 電動車充電裝置	☐☐☐☐☐

C. 充電服務安排方面

C1. 您認為充電服務較適合由以下那個/那些界別負責：（請按次序排列，排最先為最應該負責） ☐☐☐☐☐

(1) 單層巴士/小巴營運商　(2) 電力公司　(3) 政府部門

(4) 充電設施供應商（類似油站方式）　(5) 其他________________

其他意見

____

____

____

____

~ 多謝您的寶貴意見 ~

請把完成的問卷送回熊永達博士(電郵:cewthung@polyu.edu.hk 或傳真:23346389)

Appendix E: Results of Stakeholder Questionnaire Survey

推動香港單層巴士及小巴電動化的研究
第一輪問卷調查（2016年8月）結果

是次調查於2016年8月27日及10月3日舉行的兩次研討會中，以問卷形式進行，共收集到56分完成的問卷，受訪者的界別如下，當中超過一半（54%）為其他公眾人士、其餘主要為學者（14%）和營運商（11%）。

受訪者界別:	出席人數	比例
專營巴士營運商	6	11%
非專營巴士營運商	4	7%
小巴營運商	1	2%
其他小型巴士營運商	2	4%
政府部門	1	2%
電力公司	4	7%
學者	8	14%
其他	30	54%
總計：	56	100%

主要調查結果

1. 單層電動巴士/小巴的充電安排各方面的重要性（A1）

充電安排項目	重要性平均數*	首兩個最重要的項目	
		數量	比例
充電時間	1.8	43	79.6%
充電價格	3.6	4	7.5%
電池壽命/耐用情況	2.5	28	51.9%
充電方便程度	2.1	35	63.6%

*數值愈小代表愈重要

就單層電動巴士/小巴的充電安排的各個方面之重要性而言，受訪者認為「充電時間」和「充電方便程度」為最重，分別有約80%和64%受訪者認為此兩方面為最重要的首兩個項目，而最不重要的反而

是「充電價格」。

2. 單層電動巴士/小巴的發展方向（A2、A3）

單層電動巴士發展方式	發展次序平均數*	首兩個最應該的發展方式	
		數量	比例
方式一：過夜充電 + 日間充電 1 次	1.6	42	80.8%
方式二：日間多次快速充電	2.4	27	50.9%
方式三：替換電池（一至三次）	3.0	20	37.0%
方式四：超級電容 (日間多次快速充電)	2.8	18	34.6%

*數值愈小代表發展次序愈優先

電動小巴發展方式	發展次序平均數*	首兩個最應該的發展方式	
		數量	比例
方式一：過夜充電 + 日間充電 1 次	1.9	36	67.9%
方式二：日間多次快速充電	2.2	33	63.5%
方式三：替換電池（一至三次）	3.1	19	35.8%
方式四：超級電容 (日間多次快速充電)	2.8	18	34.6%

*數值愈小代表發展次序愈優先

根據調查結果顯示，大部份受訪者認為「方式一：過夜充電 + 日間充電1次」和「方式二：日間多次快速充電」為最合適的發展方向，當中超過80%受訪者認為方式一最適合單層電動巴士。而推動電動小巴方面，受訪者對方式一和方式二的支持度相當接近，分別獲得約68%和64%的受訪者支持。

3. 成本分擔情況

整體成本方面（B1）

就推動電動單層巴士/小巴方面而言，受訪者認為問卷所列的4個成本項目對他們都相當重要。調查結果顯示，各個成本項目的重要性平均數非常接近（2.1 – 2.9），其中以「電動車輛成本」方面似乎被受訪者認為較重要，約有64%受訪者認為是首兩個最重要的成本項目，其次為「電動車充電裝置」，約有57%受訪者認為是首兩個最重要的成本項目。

成本項目	重要性平均數*	首兩個最重要的項目	
		數量	比例
電動車輛成本	2.1	35	63.6%
更換電池成本	2.6	24	44.4%
安裝變壓站（火牛房）	2.9	19	35.2%

電動車充電裝置	2.3	31	57.4%

*數值愈小代表愈重要

個別成本項目方面（B2）

就分擔個別成本項目方面，大部份受訪者均認為有關政府部門是首兩個最應該分擔推動電動單層巴士/小巴的各項成本的單位（約70%~80%）。其中就「更換電池成本」方面，認為應該由有關政府部門、巴士/小巴營運商和電池供應商分擔的受訪者比例相約（45-55%）。除此以外，就「電動車輛成本」方面巴士/小巴營運商和電動車供應商也應該分擔（接近70%），在「安裝變壓站（火牛房）」和「電動車充電裝置」方面應該由充電設施供應商分擔。

界別	分擔成本次序平均數*	首兩個最應該分擔「電動車輛成本」的界別	
		數量	比例
電動車供應商	2.7	25	48.1%
電池供應商	3.6	8	15.4%
充電設施供應商	4.0	4	7.7%
政府部門	2.0	37	71.2%
巴士/小巴營運商	2.7	31	59.6%

*數值愈小代表該界別愈應該分擔「電動車輛成本」成本

界別	分擔成本次序平均數*	首兩個最應該分擔「更換電池成本」的界別	
		數量	比例
電動車供應商	3.3	15	28.8%
電池供應商	2.3	29	55.8%
充電設施供應商	3.8	11	21.2%
政府部門	2.7	24	46.2%
巴士/小巴營運商	2.7	26	50.0%

*數值愈小代表該界別愈應該分擔「更換電池成本」

界別	分擔成本次序平均數*	首兩個最應該分擔「安裝變壓站（火牛房）」成本的界別	
		數量	比例
電動車供應商	3.8	6	11.5%
電池供應商	3.9	7	13.5%
充電設施供應商	2.2	36	69.2%
政府部門	1.7	42	80.8%

巴士/小巴營運商	3.4	14	26.9%

*數值愈小代表該界別愈應該分擔「安裝變壓站（火牛房）」成本

界別	分擔成本次序平均數*	首兩個最應該分擔「電動車充電裝置」成本的界別	
		數量	比例
電動車供應商	3.5	11	21.2%
電池供應商	3.5	13	25.0%
充電設施供應商	2.7	25	48.1%
政府部門	2.0	37	71.2%
巴士/小巴營運商	3.2	19	36.5%

*數值愈小代表該界別愈應該分擔「電動車充電裝置」成本

4. 充電服務方面（C2）

在充電服務方面，電力公司、政府部門和充電設施供應商等三個單位均獲得相約（60%~68%）的受訪者認為應該分擔提供充電服務的角色。

界別	分擔成本次序平均數*	首兩位最應該分擔「充電服務」成本的界別	
		數量	比例
單層巴士/小巴營運商	3.4	7	13.5%
電力公司	2.3	35	67.3%
政府部門	2.3	31	59.6%
充電設施供應商	2.1	33	63.5%
其他	4.1	3	5.8%

*數值愈小代表該界別愈應該分擔充電服務的成本

Appendix F: Comparison of TCO for e-bus and e-minibus VS conventional bus and minibus

Scenarios				Capital Cost		Battery Replacement Cost			Operation Cost	Fuel Cost				Maintenance Cost				
Type of Charging Modes	Manufacturer	Type of Vehicles	Total Energy Capacity (kWh) (*1)	Bus Purchase Price (HKD) (*2, 12)	Charger Price (HKD) (*3,4,5,6)	Unit Price of battery (HKD/ kWh)	No. of Replacement in service life (*7)	Total Cost of Replacement in service life (HKD)	Vehicle License Fee in service life (HKD) (*8)	Yearly Mileage (km) (*9)	Mileage in service life (km)	Fuel Cost per km (HKD) (*10)	Total Fuel Cost in service life	Maintenance Cost (HKD/ km) (*11)	Total Maintenance Cost in service life	TCO in service life	TCO per km in service life	TCO in service life per year
SC	Chinese made	12m Electric SD Bus	322	$4,502,400	$84,000	$3,500	4	$4,508,000	$40,950	41700	750600	1.75	$1,313,550	3.3	$2,476,980	$12,925,880	$17.22	$718,104
SC	Foreign made	12m Electric SD Bus	322	$4,576,099	$84,000	$3,500	4	$4,508,000	$40,950	41700	750600	1.75	$1,313,550	3.3	$2,476,980	$12,999,579	$17.32	$722,199
UC	Chinese made	12m Electric SD Bus	90	$3,900,000	$116,667	$11,000	1	$990,000	$40,950	41700	750600	1.75	$1,313,550	3.3	$2,476,980	$8,838,147	$11.77	$491,008
UC	Foreign made	12m Electric SD Bus	90	$3,610,000	$116,667	$11,000	1	$990,000	$40,950	41700	750600	1.75	$1,313,550	3.3	$2,476,980	$8,548,147	$11.39	$474,897
Comparison	12m Diesel SD Bus (15 years' life)			$2,160,000	$0				$34,125	41700	625500	7.85	$4,910,175	2.85	$1,782,675	$8,886,975	$14.21	$592,465
SC	Chinese made	Electric Minibus	88	$1,050,000	$84,000	$3,500	4	$1,232,000	$151,722	112402	2023236	1.72	$3,479,966	0.81	$1,638,821	$7,636,509	$3.77	$424,251
Comparison	Diesel Minibus (15 years' life)			$539,000	$0				$126,435	112402	1686030	2.97	$5,007,509	0.77	$1,298,243	$6,971,187	$4.13	$464,746

Type of Charging Modes	Manufacturer	Type of Vehicles	Total Energy Capacity (kWh) (*1)	TCO in service life	TCO per km in service life	TCO in service life per year
SC	Chinese made	12m Electric SD Bus	322	$12,925,880.00	$17.22	$718,104.44
SC	Foreign made	12m Electric SD Bus	322	$12,999,579.00	$17.32	$722,198.83
UC	Chinese made	12m Electric SD Bus	90	$8,838,146.67	$11.77	$491,008.15
UC	Foreign made	12m Electric SD Bus	90	$8,548,146.67	$11.39	$474,897.04
Comparison		12m Diesel SD Bus **(15 years' life)**		$8,886,975.00	$14.21	$592,465.00
SC	Chinese made	Electric Minibus	88	$7,636,509.08	$3.77	$424,250.50
Comparison		Diesel Minibus **(15 years' life)**		$6,971,187.20	$4.13	$464,745.81