An Industry Study on Electric Vehicle Adoption in Hong Kong

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CONTENTS |

EXECUTIVE SUMMARY

The main purpose of conducting an Electric Vehicle (EV) Study is to examine the global trend of EV usage and its applications in Hong Kong in facilitating smart city development. Following on the previous EV study conducted in 2014, the Automotive Platforms and Application Systems R&D Centre (APAS) and Hong Kong Productivity Council (HKPC) has prepared this report in 2020 with updated findings and follow-up recommendations regarding the promotion of EVs and the recent adoption of smart mobility in Hong Kong.

In the 2014 study, it revealed the need for the Government to play a pivotal role in EV adoption, infrastructure, talent, and the general safety of the recycling of EVs and EV batteries in Hong Kong. This study reviews the implementation progress of the said recommendations in Hong Kong. Despite this, the current study conducted researches on a number of technologies that have emerged in recent years, including high-power charging, connected vehicles and autonomous driving technologies. Taking edge-cutting technologies into account, this study also makes views and recommendations to both green transportation and the emerging smart mobility sector in Hong Kong.

Chapter 1 enlists the study's purpose, background and methodology. Chapter 2 briefly reviews the top five foreign regions in terms of their EV adoption rate, the status of EV adoption in Hong Kong, together with four recommendations for Hong Kong to facilitate a wider adoption of commercial EVs. Recommendations for improving the EV charging infrastructure in Hong Kong have been made in Chapter 3. After that, the focus is on a series of emerging technologies, which are listed and discussed thoroughly in Chapter 4, with recommendations on how to support these new emerging technologies. Following this, we explore concerns about talent problems relating to repair and maintenance services offered by independent garages in Chapter 5. Issues about the decommissioning of batteries and EVs have been covered in Chapter 6 while Chapter 7 as a conclusion.

Major recommendations of this study for all the stakeholders in Hong Kong EV industry are summarised as follow:

Government policy in terms of facilitating commercial EV adoption

It is commonly known that commercial vehicles is one of the major sources of roadside emissions in Hong Kong. Improvement should be made further if these commercial vehicles are powered by electricity instead of internal combustion engines.

Recommendation 1: Offer incentives and special programmes for commercial fleets

To begin with, it is recommended that the policy makers to consider expanding EV usage among commercial fleets. For example, franchised buses, are suitable targets for electric vehicle or hybrid electric vehicle adoption schemes. Commercial fleets may also be encouraged to adopt new technologies such as battery swapping, wireless charging and super capacitors.

Recommendation 2: Provide high power charging facilities
Both the policy makers and Electric Vehicle Supply Equipment (EVSE) operators are recommended to provide high power charging facilities with a minimum of 200kW which can charge an EV within 30 minutes.

Recommendation 3: Develop commercial EVs meet the needs of Hong Kong
It is recommended that local R&D centres collaborate with Mainland China or overseas vehicle manufacturers to develop tailor-made medium-duty EVs and heavy-duty EVs that are specifically designed for the operational needs and traffic conditions present in Hong Kong. To promote EV adoption, it is also recommended that the policy makers should consider to set up more specialised and target oriented programmes like trial schemes to facilitate EV adoption progress in Hong Kong.

Recommendation 4: Provide infrastructure support for private EVs
The policy makers should promote and strengthen the deployment of EVSE with a more strategic vision for EV infrastructure support. Similar to other regions, this can be achieved through incentive programmes, tax concessions and pilot programmes.

The setup of EV charging infrastructure

Recommendation 5: Create connections between stakeholders
In order to establish a more sophisticated EV charging network in Hong Kong, the local market could form an industrial platform to build common targets, goals and strategies for the development of EV charging infrastructure. The industrial platform can also connect key stakeholders including the government, the power companies, charging service providers, property management offices, universities, R&D institutes and EV user groups.

Recommendation 6: Encourage private sector's participation and promote paid charging services
It is no doubt that encouraging the private sector to enter the market is a more sustainable solution to cater market demand as well as easing the government's burden on providing EV charging service, therefore, the policy makers should encourage the private sector in developing paid charging facilities.

Recommendation 7: Support the development of innovative charging technologies
The policy makers could select dedicated demonstration sites to centralise the demonstration and trial of EV charging technologies. Through these sites, it can facilitate more experience sharing and knowledge exchange among the academic, research and industry sectors, which will naturally foster the technology development.

Emerging EV technologies

Recommendation 8: Support for and testing of emerging EV technologies
Regarding the development of emerging EV technologies in Hong Kong, the policy makers could provide financial incentives and testing facilities for the power companies, charging service providers, telecommunications service providers, open data providers, property management offices, universities, R&D institutes, EV user groups and other interested parties as they work together to build common targets, goals, strategies and road maps. The policy makers should also review current regulations, identify obsolete or out-dated regulations, and set up new regulations and a legislative framework that are applicable to new EV technologies.

On the other hand, if the policy makers provide funding support for the test bed of advanced and emerging EV technologies in Hong Kong, it may hasten the pace of commercialisation and attract investment from the private sector.

Also, the policy makers could deploy a 5G network and set up a common platform for data sharing among developers, manufacturers and stakeholders to support the development of V2X technologies and autonomous driving.

Talent development

The under-supply of qualified EV mechanics and independent EV service garages in Hong Kong continue to raise concerns over the convenience, cost and safety of EVs in the city, which constitutes a major obstacle for car owners who are contemplating to switch to an EV.

Recommendation 9: Fulfil the latest Specification of Competency Standards for EV training

It is recommended that the automotive industry and training institutions should introduce training courses immediately to fulfil the EV competency standards as stated in the latest version of "Specification of Competency Standards"[1]. This will promote the professional identity for EV practitioners and improve the overall quality of EV maintenance and service.

Recommendation 10: Strengthen and enrich the content of EV training curricula

Nurturing talents is one of the concerned areas, in view of that, Hong Kong's educational institutions should strengthen and enrich the content of their EV training curricula to fulfil the growing demand for EV maintenance and service. At the same time, EV manufacturers should disclose relevant EV diagnostic tools, equipment and detailed service manuals to these institutes for educational purposes. Finally, it is recommended that local EV dealerships to provide short-term internship positions that allow students to learn and develop EV maintenance and service skills.

The decommissioning of EV batteries

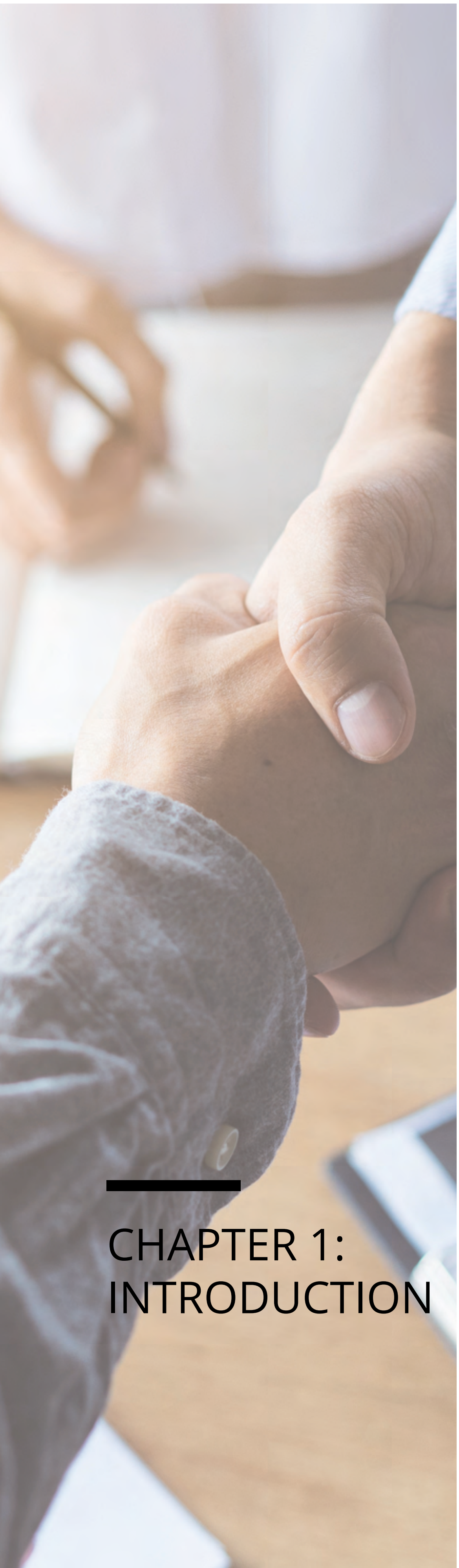
Recommendation 11: Promote battery recycling to the commercial sector

It is recommended that the policy makers to play a more active role in promoting battery recycling to the commercial sector and encourage more demonstration projects for second life battery.

Recommendation 12: Make the best use of the existing funding schemes to help the development of the battery recycling industry

To support the sustainable development of the recycling industry, the policy makers announced in its 2014 Policy Address that HK$1 billion has been earmarked to set up a Recycling Fund. The interested parties should make the best use of the funding scheme to help the development of the battery recycling industry.

1 *Qualifications Framework, Automotive Industry, Specification of Competency, 2019, retrieved from https://www.hkqf.gov.hk/filemanager/automotive/common/scse/automotive/v2/Automotive_Eng_SCS_Version_2_2019-7-29.pdf*



CHAPTER 1: INTRODUCTION

1.1 Background of this study

This report aims to present the findings and recommendations of a study on the promotion of Electric Vehicle (EV) adoption in Hong Kong. The study was conducted by Automotive Platforms and Application Systems (APAS) R&D Centre, in collaboration with Hong Kong Productivity Council.

The Government of the Hong Kong Special Administrative Region (HKSAR) has been promoting the adoption of EVs in both the private and commercial sectors for years. In March 2009, a steering committee led by the Financial Secretary was set up to promote the use of EVs in Hong Kong. In 2010, the HKSAR set up a HK$300 million Pilot Green Transport Fund to support the testing of green and innovative technologies, which are applicable to the public transport sector and goods vehicles.

In October 2014, APAS and HKPC issued a study named “An Industry Study on Electric Vehicle Adoption in Hong Kong”, which reviewed the state of EV adoption in selected foreign countries and in Hong Kong. The study made 13 recommendations on promoting the adoption of EVs for private cars and commercial vehicles.

1.2 Follow up actions to previous recommendations

In the “An Industry Study on Electric Vehicle Adoption in Hong Kong” report, released in 2014, 13 recommendations were made in five areas: the role of the Government, EV charging infrastructure, talent development, type approval and safe disposal. In this report, we review the implementation status of these recommendations, with the findings presented in chapters corresponding to the recommendations.

1.3 Methodology of this study

1.3.1 Conducting international surveys and collecting local views

Part of the research for this study consisted of market surveys and desktop research regarding EV adoption in major markets around the world. Existing government policies in these foreign markets pertaining to the promotion of EV adoption were also reviewed, to provide a holistic view of good practices that are being implemented, and to help identify specific needs relevant to Hong Kong context that will help us to achieve green transportation by adopting EVs in both the private and commercial sectors.

Interviews and surveys were also conducted with major local stakeholders to collect their views and concerns on EV adoption. These included government departments and bureaus, educational institutions, commercial fleet operators, trade unions, property developers, and management offices.

1.3.2 Providing information to facilitate a holistic plan by policy makers

The number of EVs for road use in Hong Kong increased from less than 100 in end 2010 to 13,866[2] in the end of December 2019. During the stakeholder interviews, we learned that there are vast differences between EVs and internal combustion engine vehicles in many areas – in terms of the overall business models of manufacturers, service providers and other related organisations; consumer usage behaviour; the charging infrastructure; type approval; and technician training for repairing and maintenance. Therefore, same as the case in other markets around the world, it is very important to create a holistic plan for Hong Kong's readiness for EV adoption, and to provide support the realisation of this plan.

In order to understand the need from the industry, APAS has set up an Electric Vehicle Stakeholder Interest Group (EVSIG), which holds regular meetings to collect the views and concerns of stakeholders. Through meetings with EVSIG members, APAS discovered that the industry is currently facing a number of issues that could provide significant obstacles to the growth of both the local EV industry and the wider adoption of EVs in Hong Kong, so much that growth could be stifled entirely. These issues are broadly related to the installation costs and locations of EV charging infrastructure, the current charging time for EVs, the short lifespan of most EV batteries, type approval testing and standards to be adopted, the fact that most regulations were originally conceived and designed for internal combustion engine vehicles, and the shortage of qualified EV maintenance personnel.

1.3.3 Identifying five key EV adoption areas

Based on interviews and desktop surveys conducted with local stakeholders, this study identified five key areas in the EV industry infrastructure and ecosystem that need special attention and support in order to reduce barriers to the adoption of EVs.

These five areas are:
a) Government policies facilitating the adoption of EVs;
b) The setup of EV charging infrastructure;
c) Emerging EV technologies;
d) Talent development for EV maintenance and support;
e) The decommissioning of EV batteries and EVs.

2 *VALID & Licensing Division, Monthly Traffic and Transport Digest, Dec2019, retrieved from https://www.td.gov.hk/filemanager/en/content_4947/table44.pdf*

CHAPTER 2: THE CURRENT STATE OF THE GLOBAL EV MARKET

2.1 Global EV adoption trends

All over the world, EVs are being widely welcomed as the “latest and greatest” type of transportation. Most of the world’s major automakers are planning to produce more EVs in the coming 10 to 15 years. Some countries have even announced a ban to the sale of Internal Combustion Engine (ICE) vehicles within the next 10 to 20 years – for example, Norway plans to enact a ban in 2025, while France and the UK plan to ban ICE vehicles by 2040.

2.1.1 The current EV adoption status in the “top five” EV adoption markets[3]

This section briefly reviews the EV adoption status in the top five EV adoption markets. In descending order of the adoption rate, these markets are: Norway, the Netherlands, Sweden, France and the UK. In addition, the US and Mainland China accounted for about 22 per cent and 45 per cent of the global stock of EVs in 2018[4]. The adoption status of the US and Mainland China is also presented in this section as well.

Norway

Norway led the EV market in 2019 in terms of market share. Norway has achieved full commercialisation of its EV industry due to a combination of incentives and tax breaks given by the government. This “electric boom” has resulted in the emergence of an e-mobility value chain, which is made up of charging infrastructure, electric companies and charging station owners.

EV subsidies and tax breaks given in Norway in 2020[5]

VAT	Zero-emission vehicles are exempt from Value Added Tax (VAT) – which on average in Norway adds 25% to the cost of a vehicle – and other taxes on vehicle purchases and leasing. This VAT exemption will remain in place until the end of 2020. The scheme will be revised and adjusted parallel with the market development.
Purchase/Import Tax	EVs are exempt from Purchase/Import Tax.
Company Car Tax	The company car tax is 40% lower for EVs.
Registration Tax	EVs are exempt from Vehicle Registration Tax.
Annual Road Tax	EVs are exempt from annual road tax.
Access to Bus Lane	EVs have access to the bus lanes in most Norwegian towns and cities.
Parking	Parking fee for EVs is implemented locally but with an upper limit of a maximum 50% of the full price.
Road Toll	Road toll fee for EVs is implemented with an upper limit of a maximum 50% of the full price.
Reduction of Ticket Fee on Ferries	Since 2018, EVs have received a 50% reduction in ticket fees on ferries.

3 *MarketsandMarkets, EV Infrastructure and EV Components Market, Global Forecast to 2021, 2017*
4 *International Energy Agency, Global EV Outlook 2019, 2019, retrieved from https://www.iea.org/reports/global-ev-outlook-2019*
5 *Norsk elbilforening, Norwegian EV policy, retrieved from https://elbil.no/english/norwegian-ev-policy/*

Other Benefits	Drivers using company cars have to pay a certain fee when using these vehicles for private driving. However, if these vehicles are Battery Electric Vehicles (BEVs) or Plug-in Hybrid Electric Vehicles (PHEVs), the imposed fee is halved when compared to other types of vehicles.

The Netherlands

The Netherlands has one of the highest EV adoption rates in the world, and this is primarily driven by incentives. The Netherlands’ vehicle taxation scheme involves a CO2-based rebate for vehicles that emit less than 50g of CO2 per kilometre – a scheme which has contributed to a surge in growth of the EV market.

Subsidies and tax breaks in the Netherlands in 2020

<table>
<tr><td>Registration Tax[6]</td><td>Zero emission cars are exempt from registration tax.
In 2020, for conventional ICE vehicles, there are six levels of CO2 emissions. And a fixed surcharge of €366 is applied to all new vehicles sold with CO2 emissions of 1g/km or more. After that, a rate is charged for every grams of CO2 per km within a certain range. For a vehicle with a diesel engine, extra €88.43 is charged for every grams of CO2 per km above 59 g/km.
<table>
<tr><td>Thresholds for CO_2 (g/km)</td><td>Tax per gram of CO_2 /km (€)</td></tr>
<tr><td>0</td><td>0 (exempt)</td></tr>
<tr><td>1 - 68</td><td>2</td></tr>
<tr><td>69 - 91</td><td>59</td></tr>
<tr><td>92 - 133</td><td>129</td></tr>
<tr><td>134 - 150</td><td>212</td></tr>
<tr><td>> 150</td><td>424</td></tr>
</table>
For PHEVs, there are four levels of CO2 emissions with no fixed surcharge.
<table>
<tr><td>Thresholds for CO_2 (g/km)</td><td>Tax per gram of CO_2 /km (€)</td></tr>
<tr><td>0</td><td>0 (exempt)</td></tr>
<tr><td>1 - 30</td><td>27</td></tr>
<tr><td>31 - 50</td><td>111</td></tr>
<tr><td>> 50</td><td>267</td></tr>
</table>
</td></tr>
<tr><td>Motor Vehicle Tax[7]</td><td>Passenger cars with zero CO2 emissions are exempt from Motor Vehicle Tax until 2024.</td></tr>
<tr><td>Income Tax[8]</td><td>A surcharge on income tax must be paid for the private use of a company car if the personal mileage exceeds 500km per year. For conventional vehicles, this is enacted by imposing 22% of the catalogue value of the car on the person’s taxable income. For BEV, this amounts to 8% up to a maximum amount of €45,000 from the catalogue value. For the amount above, the general addition percentage of 22% applies.

Tax deductible investments[9]: When purchasing a EV, entrepreneurs can receive a subsidy in the form of an extra depreciation item, which reduces the taxable profit of a company and means that they can pay less income tax.</td></tr>
</table>

6 ANWB, BPM: Belasting van Personenauto's en Motorfietsen, retrieved from https://www.anwb.nl/auto/autobelastingen/bpm
7 ANWB, MRB of Motorrijtuigenbelasting, retrieved from https://www.anwb.nl/auto/autobelastingen/mrb
8 ANWB, Bijtelling, retrieved from https://www.anwb.nl/auto/autobelastingen/bijtelling
9 ANWB, Wat kost elektrisch rijden?, retrieved from https://www.anwb.nl/auto/elektrisch-rijden/wat-kost-het

Sweden

Sweden has a robust existing infrastructure, which gives people easy access to vehicle chargers. Sweden now has more EVs, per thousand people, than the US.

Subsidies and tax breaks in Sweden in 2020

Subsidies[10]	• In Sweden, the highest subsidy offered to BEV owners is SEK 60,000. This subsidy is granted for an amount no more than 25% of the vehicle's price when the car model was first introduced on the Swedish market. For the vehicles emit a maximum of 60 grams of carbon dioxide per kilometre, the subsidy will then be reduced by SEK833 for every gram of CO2 emitted kilometre. When a company purchases a vehicle, the subsidy will not exceed 35% of the price difference between the EV and a comparable petrol or diesel-powered vehicle. • The Swedish government has provided a 21 million euro subsidy to cut the price of PHEVs and EVs.
Company Car Tax[11]	For electric and plug-in hybrid vehicles, the taxable value of the car for the purposes of calculating the benefit in kind of a company car under personal income tax is reduced by 40% compared with a corresponding or comparable petrol or diesel car. For the period between 2017 and 2020, the maximum reduction in the taxable value is SEK10,000.
Other Incentives[12]	Sweden has introduced its 'Klimatklivet' programme, which is an investment incentive initiative for local and regional projects that aim to reduce CO2 emissions. Its policies include incentives for EV charging infrastructure. This programme will support up to 50 % of the investment in both public and private charging stations.
Parking Fee Exemption	EVs in Sweden have access to free parking in about half of the cities in the country.

France

The French government is heavily promoting the use of EVs to achieve its target of two million EVs on the road by 2020. Automobile manufacturers like Renault, PSA, Bolloré and others had launched their first EVs and their first rechargeable hybrids by the end of 2012. Spurred on by this flurry of activity, BMW chose France as the place to run trials of its new electric Mini. Meanwhile, a Renault-Nissan alliance is developing 100% electric power trains with power ratings of between 15kW to 100kW.

Subsidies and tax breaks in France in 2020

Subsidies[13]	The subsidy is a financial aid to buy or rent a new energy efficient vehicle. The bonus concerns the purchase or long-term rental (2 years or more) of the following vehicles: car or van emitting a maximum of 20g of CO2 / km; 2 wheels, 3 wheels, motorized quadricycle using electricity as an energy source.

10 *Transportstyrelsen, Bonus- for low emission vehicles, retrieved from https://transportstyrelsen.se/en/road/Vehicles/bonus-malus/bonus/*

11 *European Automobile Manufacturers Association, Electric Vehicles: Tax benefits & incentives in the EU, 2019, retrieved from https://www.acea.be/uploads/publications/Electric_vehicles-Tax_benefits_incentives_in_the_EU-2019.pdf*

12 *Wallbox, EV and EV Charger Incentives in Europe: A Complete Guide for Businesses and Individuals, 2019, retrieved from https://wallbox.com/en_uk/guide-to-ev-incentives-europe*

13 *Service-public.fr, Ecological bonus for an electric vehicle, 2020, retrieved from https://www.service-public.fr/particuliers/vosdroits/F34014*

	• For a vehicle of less than €45,000, including if necessary the cost of buying or renting the battery, the bonus is 27% of the acquisition cost including the tax. The subsidy is capped at €6,000. • For a vehicle between €45,000 and €60,000, including if necessary the cost of buying or renting the battery, the subsidy is €3,000. • For a vehicle over €60,000, including if necessary the cost of purchasing or renting the battery, the bonus only concerns the light utility vehicles and hydrogen powered vehicle, the subsidy is €3,000.
License Plate Tax[14]	Both fully electric and plug-in hybrid vehicles are eligible for either a 50% discount or are entirely exempt from the License Plate Tax, depending on the region.
Company Car Tax[15]	BEVs and vehicles which emit less than 60 grams of CO2/km are exempt from company car tax that is calculated based on atmospheric pollutant emissions.
Conversion Premium[16]	A conversion premium is granted to vehicle owners of buying an environmentally friendly vehicle and scrapping their older diesel or petrol vehicle at the same time. The amount of the premium varies according to the emissions produced by the new vehicle and other conditions such tax reference income and driving distance per year. This conversion premium can be combined with the subsidy mentioned above, with the total amount of both bonuses potentially reaching €11,000.

The United Kingdom (UK)

The adoption of EVs in the UK is strongly supported by the UK government through incentives and subsidies. The EV market in the UK is growing rapidly, especially in terms of vehicles and charging infrastructure. In recent years, the UK has experienced tremendous growth in the EV market, and is expected to do better in the future.

Subsidies and tax breaks in the UK in 2020

Subsidies[17]	For the category of Cars (previously 'category 1'), people who purchase a car have CO2 emissions of less than 50g/km and can travel at least 112km (70 miles) without any emissions can receive a grant of 35% of the purchase price of the vehicle, up to a maximum of £3,500.
Vehicle Tax[18]	BEVs have zero CO2 emission are exempt from the first Vehicle Tax payment. BEVs with list price under £40,000 are exempt from the Annual Vehicle Tax after the first year of purchase.
Company Tax Benefits[19]	EVs and PHEVs with low CO2 emission can deduct part of the value from the profits before tax.
Local Incentives[20]	BEVs, PHEVs, range-extended EVs and hydrogen fuel cell EVs are exemption from congestion charge in London.

14 *Service-public.fr, Cost of registration card, 2020, retrieved from https://www.service-public.fr/particuliers/vosdroits/F19211*
15 *Service-public.fr, Company vehicle tax, 2019, retrieved from https://www.service-public.fr/professionnels-entreprises/vosdroits/F22203*
16 *Service-public.fr, Conversion bonus (scrap bonus) to replace an old vehicle, 2020, retrieved from https://www.service-public.fr/particuliers/vosdroits/F32487*
17 *GOV.UK, Low-emission vehicles eligible for a plug-in grant, retrieved from https://www.gov.uk/plug-in-car-van-grants*
18 *GOV.UK, Vehicle tax rates, retrieved from https://www.gov.uk/vehicle-tax-rate-tables*
19 *GOV.UK, Claim capital allowances, retrieved from https://www.gov.uk/capital-allowances/business-cars*
20 *Transportation for London, Electric vehicles and charge points, retrieved from https://tfl.gov.uk/modes/driving/electric-vehicles-and-rapid-charging*

The United States (US)

The US is one of the world's top nations in terms of the global EV market. In 2019, the US accounted for about one quarter of the world's EVs, lagging only behind Mainland China in terms of number of EVs. Increasing environmental awareness among consumers is expected to further drive sales of EVs in the near and mid-term.

Subsidies and tax breaks in US in 2020

Tax Credit[21]	For every new BEV or PHEV purchased for use in the US, a Federal Internal Revenue Service (IRS) tax credit is up to USD7500. The amount of the tax credit is dependent on the size of the vehicle and its battery capacity.
Discounts on Insurance	A number of major insurance companies offer discounts of 5% or more for owners of EVs and HEVs.
Car Pool Lane access	Certain American states provide carpool lane access for EVs. This enables consumers to bypass traffic jams and acts as a powerful incentive for purchasing EVs.

Mainland China

Mainland China has the world's largest electric car market. In Mainland China, BEVs and PHEVs are known as New Energy Vehicles (NEVs). Around 821,000 BEVs and 203,000 PHEVs were sold in 2019. The sale of NEV increased by 3% compared with 2018[22]. In 2019, Mainland China accounts for nearly half of the global electric car market.

Subsidies and tax breaks in Mainland China in 2020

Subsidies provided by central government[23]	• Subsidies are available for all BEVs that can travel a minimum of 250km on a single charge and with power densities of the traction battery no less than 125Wh/kg. • Initiatives to promote the adoption of NEVs include passenger car purchase subsidies, with the baselines of RMB18,000 for BEVs with driving range from 250km to 400km, RMB25,000 for BEVs with driving range more than 400km, and RMB10,000 for PHEVs. The actual subsidies depend on the power densities of the traction battery and the energy consumption level. These subsidies are fixed to the end of 2020. • The subsidies are not granted directly to end consumers, rather they are forwarded to automakers who then pass these benefits on to the consumers. • These subsidies are restricted to vehicles that adhere to the "Three Transverses and Three Longitudes", an R&D strategy implemented by Mainland China's Ministry of Science and Technology. The "transverses" are three vehicle technologies (BEVs, PHEVs and fuel cell vehicles) and the "longitudes" are the core components of these technologies (batteries, motors and battery management systems). • To qualify for subsidies, the vehicle drivetrain must use at least one of the transverse technologies and one of the longitudes. Additionally, the components must be manufactured in Mainland China.

21 *Fuel Economy, Federal Tax Credits for All-Electric and Plug-in Hybrid Vehicles, retrieved from https://fueleconomy.gov/feg/taxevb.shtml*

22 *CPCA, 2019年12月份國乘用車市場深度分析報告月份國乘用車市場深度分析報告, 2020, retrieved from http://www.cpcaauto.com/newsList.asp?types=csjd&id=10406*

23 *Ministry of Finance of the People's Republic of China, 關於進一步完善新能源汽車推廣應用財政補貼政策的通知, 2019, retrieved from http://www.mof.gov.cn/mofhome/jinjijianshesi/zhengwuxinxi/zhengcefagui/201903/t20190326_3204190.html*

Other Benefits	• Local governments have specific incentives and polices for NEVs. • In Beijing, cars with odd and even license plate numbers can only drive on alternate days. However, EVs are exempt from this rule. • Generally, subsidies provided by local governments should not exceed 50% of the subsidies provided by the central government.
Vehicle Acquisition Tax[24]	Specific models of NEVs are exempt from Vehicle Acquisition Tax until the end of 2020. The list of these vehicles is updated by Ministry of Industry and Information Technology periodically.
Access to Number Plates	Mainland China employs a number of innovative non-financial incentives to encourage the purchase of EVs. These include granting license plates without a lottery process and lifting the usual driving restrictions by plate number in highly congested cities.

2.1.2 Countries which ban the sale of combustion engine vehicles

In order to further eliminate vehicle exhaust emissions, some countries plan to entirely ban the sale of vehicles with internal combustion engines in the near future. As the country with the highest EV adoption rate, it is no surprise that Norway has defined a clear and ambitious target: all new passenger cars and vans sold in 2025 must be zero-emission vehicles[25].

Meanwhile Emmanuel Macron's government has announced that France will end sales of petrol and diesel vehicles by 2040 as part of an ambitious plan to meet the country's targets under the Paris climate accord[26].

The UK is also set to ban all new petrol and diesel cars and vans from 2040, amid fears that rising levels of nitrogen oxide emissions pose a major risk to public health. The UK's commitment, which follows the similar pledge made by France, is part of the government's much-anticipated Clean Air Plan, which has been at the heart of a protracted high court legal battle[27].

The Netherlands has mooted a 2025 ban for diesel and petrol cars, and some federal states in Germany are keen on a 2030 phase-out[28]. Finally, India, where scores of cities are blighted by dangerous air pollution, is mulling the idea of no longer selling petrol or diesel cars by 2030, and has said that it wants to introduce EVs in "a very big way"[29]. It is likely that by 2040, most vehicles running on India's roads will be powered by electricity.

2.1.3 Automakers' strategies

In response to the policy of banning the sales of internal combustion engine vehicles in some countries, automakers around the world are working hard to speed up their production of EVs.

From 2019 onwards, all new cars launched by Volvo will be partially or completely battery-powered, in what the company calls a "historic end" to building models with only internal combustion engines. Between 2019 and 2021, Volvo will introduce five 100% electric models, and ensure that the rest of its conventional petrol and diesel models have hybrid engines of some form. Volvo is the first major vehicle manufacturers to make such a bold move[30].

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24 *State Taxation Administration, 關於免徵新能源汽車車輛購置稅的公告, 2017, retrieved from http://www.chinatax.gov.cn/n810341/n810755/c2985330/content.html*

25 *Norway Government, Norway's low emissions policy, Jul 2018, retrieved from https://www.regjeringen.no/en/aktuelt/norways-low-emissions-strategy/id2607245/*

26 *Reuters, France to uphold ban on sale of fossil fuel cars by 2040, Jun 2019, retrieved from https://www.reuters.com/article/us-france-autos/france-to-uphold-ban-on-sale-of-fossil-fuel-cars-by-2040-idUSKCN1TC1CU*

27 *BBC News, New diesel and petrol vehicles to be banned from 2040 in UK, Jul 2017, retrieved from https://www.bbc.com/news/uk-40723581*

28 *The Guardian, automotive industry, France to ban sales of petrol and diesel cars by 2040, Jul 2017, retrieved from https://www.theguardian.com/business/2017/jul/06/france-ban-petrol-diesel-cars-2040-emmanuel-macron-volvo*

29 *The Guardian, automotive industry, France to ban sales of petrol and diesel cars by 2040, Jul 2017, retrieved from https://www.theguardian.com/business/2017/jul/06/france-ban-petrol-diesel-cars-2040-emmanuel-macron-volvo*

30 *The Guardian, automotive industry, All Volvo cars to be electric or hybrid from 2019, Jul 2017, retrieved from https://www.theguardian.com/business/2017/jul/05/volvo-cars-electric-hybrid-2019*

Jaguar Land Rover has become the latest large carmaker to say it will stop launching new models solely powered by internal combustion engines, making the announcement two months after Volvo. The UK-based manufacturer has promised that all new models from 2020 will be fully electric or hybrid. This timeline is a year later than Volvo's target, but it is a big step beyond the unveiling last November of a single electric concept car[31].

Daimler is among the most ambitious of the legacy automakers when it comes to the electrification of their vehicle line-up, with plans for 10 new all-electric models and a planned 15 to 25 per cent of all their production being electric by 2025. At Daimler's Annual Shareholder's Meeting in Berlin Germany, the company announced an acceleration of these plans. They are aiming to start producing these new EVs by 2022 – 3 years sooner than previously announced[32].

Volkswagen (VW) has announced that it will spend over USD24 billion producing EVs by 2030 and will have a zero-emissions version of each of its models, similar to Mercedes-Benz. As part of its bold investment strategies, VW has set a goal of 80 new EVs across all its brands by 2025, previously, they had aspired to launch 30 EVs. Furthermore, the company plans to offer an electric version of each of its existing 300 models by 2030[33].

2.2 The current status of EV adoption in Hong Kong

According to statistics from HKSAR Government's Transport Department, by the end of November 2019, the total number of EVs registered in Hong Kong was 13,358. When compared to figures from August 2014, the total number of EVs increased from 782 to 13,358; there have been a 16-fold increase in just five years. The number of EVs has been broken down by vehicle type as of November 2019 is shown in Table 2-1.

Vehicle type	**Number of vehicles (as at Aug 2014)[34]**	**Number of vehicles (as at Nov 2019)[35]**	**Change in number**	**Change in percentage**
Motorcycles	45	18	-27	-60.0%
Private cars	515	13,066	+12,551	+2437.1%
Taxis	48	0	-48	-100.0%
Franchised buses	0	34	+32	N/A
Private buses	4	2	-2	-50.0%
Private light buses	4	6	+2	+50.0%
Other non-franchised public buses	2	8	+6	+300.0%
Light goods vehicles	50	120	+70	+140.0%
Medium goods vehicles	2	0	-2	-100%
Special purpose vehicles	112	104	-8	-7.1%
Total number of registered EVs	**782**	**13,358**	**12,576**	+1608.18%

Table 2-1 Registered EVs by type (as of August 2014 and November 2019)

31 *The Guardian, Jaguar Land Rover to make only electric or hybrid cars from 2020, Sept 2017, retrieved from https://www.theguardian.com/business/2017/sep/07/jaguar-land-rover-electric-hybrid-cars-2020*

32 *Electrek, Daimler announces acceleration of electric car plans by 3 years, will spend $11 billion on 10 models by 2022, Mar 2017, retrieved from https://electrek.co/2017/03/29/daimler-accelerate-electric-car-plan-2022/*

33 *Engadget, Volkswagen wants 300 EV models by 2030, Sept 2017, retrieved from https://www.engadget.com/2017/09/11/volkswagen-wants-300-ev-models-by-2030/*

34 *VALID & Licensing Division, Monthly Traffic and Transport Digest, Aug 2014, retrieved from http://www.td.gov.hk/filemanager/en/content_4668/1408.pdf*

35 *VALID & Licensing Division, Monthly Traffic and Transport Digest, Nov 2019, retrieved from https://www.td.gov.hk/filemanager/en/content_4947/table44.pdf*

2.2.1 Current status of EV adoption in private cars

Figure 2-1 shows the number of electric private cars in Hong Kong from August 2014 to November 2019, by month. The number of private car EVs in August 2014 was 515, an adoption rate of 0.1%. This number rose to 13,066 in November 2019, an increase of 25 times; however, the adoption rate of 2.08% was still comparatively low.

The number of EVs increased gradually from August 2014 to September 2015, an average growth rate of about 153 EVs per month. At that time, people were concerned about the performance of EVs, the availability of EV charging facilities and the mileage of EVs, i.e. the absolute range of an EV on a full charge. In those days, common EV models had a range of around 100-120km per full charge. This comparatively short range explains the relative consumer reluctance to purchase EVs at that time.

However, when the US EV brand Tesla achieved a range of 300km plus after 2015, the picture changed. Tesla launched their electric sedan in Hong Kong in 2015, with a comparatively higher range of more than 200km per charge, these vehicles proved popular with Hong Kong people and they dominated the EV market in Hong Kong in the fourth quarter of 2016.

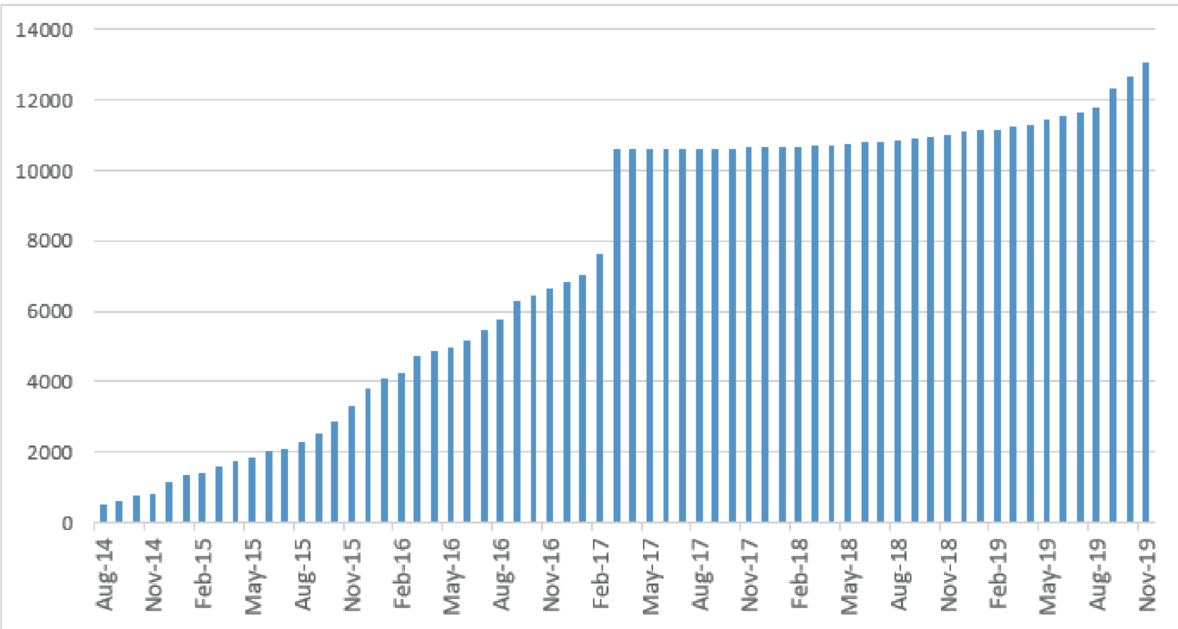

Figure 2-1 Number of registered electric private cars in Hong Kong
(Source: HKSAR Transport Department figures)

2.2.2 Current status of EV adoption in electric commercial vehicle adoption

In stark contrast to the electric private car adoption rate, the electric commercial vehicle adoption rate is not satisfactory. Figure 2-2 reveals that the number of EVs registered for commercial use has remained more or less the same over the past four years. The average number of registered electric commercial vehicle is only 269; an adoption rate of only 0.12%. As Table 2-1 shows, most commercial EVs are either light duty goods vehicles or special purpose vehicles, making up 224 in total. There are also 34 electric buses running as franchised buses. It should also be noted that as of November 2019, no electric taxis were registered in Hong Kong. The trial programme of electric taxi made by Chinese brand BYD stopped in 2015. The reason for the abysmally low adoption rate for electric commercial vehicles should be studied.

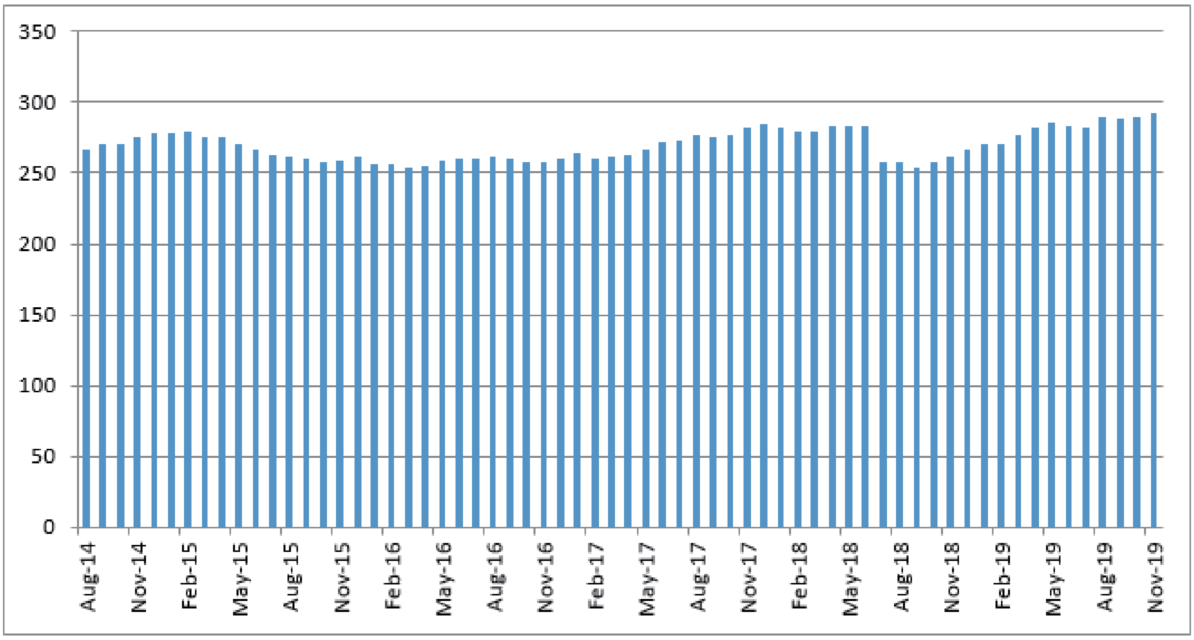

Figure 2-2 Number of registered electric commercial vehicles in Hong Kong
(Source: HKSAR Transport Department figures)

2.2.3 Availability of EV chargers in Hong Kong

As at the end of December 2019, there are 2,929 EV chargers for public use including 1,108 medium chargers in Hong Kong. These chargers were located in all 18 districts of Hong Kong in various types of buildings. There are now 588 quick chargers set up at various districts, such that there is one within around 10 km[36].

2.3 Challenges in EV adoption in private cars

2.3.1 Lack of charging infrastructure

Private car owners have stated that they would be willing to use EVs more if charging facilities were available in their homes, meaning that they could recharge their EVs at night. However, at the moment, charging facilities are mainly available in government car parks, shopping malls and other public areas only, with a few charging facilities available in private residential buildings. This means that electric private car drivers need to leave their homes to recharge their vehicles.

2.3.2 Better management of public charging facilities needed

A persistent irritant for electric private car drivers is that public parking places with charging facilities are frequently occupied by non-electric vehicles. This is a common situation in public car parks. As the number of charging facilities is already low, the situation is getting worse due to this parking place mismatch. A similar problem is EVs remaining at these public charging points even after the charging process has been completed. Better management of public charging facilities is surely needed.

36 *Environmental Protection Department, Installation of EV Chargers, retrieved from https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/promotion_ev.html*

2.3.3 Private garages cannot repair EV drive chains and power systems

The drive chains and power systems of EVs are totally different from conventional internal combustion engine vehicles. Repair and tuning of these drive chains and power systems require a high level of knowledge of electronics and information technology. Also, EVs have high voltage power chain systems, with serious potential hazards of electric shock and even fire. Common ICE automotive mechanics do not have the correct skill set to repair these vehicles. Moreover, the factory settings and the tuning parameters of most electric vehicles are proprietary knowledge of the EV maker, with most brands unwilling to release these details on the open market. This leads to a situation whereby EVs need to be repaired by only the original manufacturer or their dealers, which can considerably lengthens the service downtime of EVs.

2.4 Challenges in EV adoption in commercial vehicles

Commercial vehicle operators face more challenges to integrating EVs into their fleet as compared to the private car users.

2.4.1 More parking places for charging required

There are not enough parking places for commercial vehicles in Hong Kong – commercial vehicles of any kind. According to the report of HKSAR Audit Commission, until 31 Dec 2018, there are 73,051 commercial vehicles in Hong Kong, but only 46,955 designated parking places for them. Most lorries and buses are seen parked in rural area as temporary car parks. The power supply in these car parks is limited, and there are no incentives for the owners of these car park owners to install charging facilities.

2.4.2 "Dead mileage" arising from the charging process

As with electric private cars, commercial electric vehicles also have to use public charging stations. When they return from these charging stations to their depots, a certain amount of electricity is consumed. This "dead mileage" reduces the effective mileage and operation time of electric commercial vehicles.

2.4.3 Shortening the charging time is essential

Charging time for commercial vehicles are currently too long. Compared to private electric cars, electric commercial vehicles normally require more power, as most of them are heavy duty vehicles with a correspondingly larger battery capacity. Though there are nearly 1,500 locations where Electric Vehicle Supply Equipment (EVSE) is located around Hong Kong, around 1,300 of them are level one and level two chargers, both of which take more than four hours to fully charge a heavy duty commercial vehicle. However, the business model of most commercial fleet operators means that they cannot accept a charging time of longer than one hour.

2.4.4 More EV models needed for different applications

Currently, there are not enough EV models that are appropriate for commercial operations. There are many types of commercial vehicles. Other than vans, vehicle types include crane lorries, refuse collection vehicles, pressure tankers, oil tankers, dump trucks and many others. While EV manufacturers are focusing on developing passenger-centric EVs, like sedans, mini-buses and coaches, there are very limited electric special duty vehicle models. Given the situation, commercial fleet operators are still heavily reliant on diesel engine vehicles for their operations.

2.5 EV promotional incentives in Hong Kong

Hong Kong has been promoting the use of EVs for some time through various programmes including First Registration Tax (FRT) concession for electric vehicles, Profits Tax Deduction for Capital Expenditure on Environment-friendly Vehicles scheme, and Pilot Green Transport Fund.

2.5.1 First Registration Tax (FRT) concession

HKSAR policy makers began waiving the FRT for EVs in 1994. This scheme was extended in 2009, in 2014 and updated again on 28 February 2018. FRT concessions for EVs for the period from 1 April 2018 to 31 March 2021 are as follows[37]:

i) Electric private cars – the FRT will be waived up to HKD 97,500; and a new "One-for-One Replacement" scheme will run from 28 February 2018 to 31 March 2021, allowing private car owners who first register a new electric private car and who then arrange to scrap and de-register their own eligible old private cars – private cars with an internal combustion engine or electric private cars – to enjoy a higher FRT concession, up to a maximum of HKD250,000.

ii) Electric commercial vehicles – including goods vehicles, buses, light buses, taxis, and special purpose vehicles – along with electric motorcycles and electric motor tricycles will have their FRT waived in full.

2.5.2 Profits tax deduction for EV expenditure

Starting from 18 June 2010, commercial companies that have purchased eligible environmentally friendly vehicles may deduct the capital expenditure incurred in the purchase under their profits tax. This new tax concession was applicable in the 2010/11 year of assessment and thereafter. This tax concession covers all types of EVs.

2.5.3 Pilot Green Transport Fund[38]

As a whole, the transport sector, including various modes of road and marine transport, is the second-largest source of air pollution in Hong Kong. It accounts for about 57 per cent of respirable suspended particulates, 62 per cent of nitrogen oxides and 48 per cent of the sulphur dioxide emissions in the SAR. The sector is also responsible for about 17 per cent of all local greenhouse gas emissions, and exhaust emissions from motor vehicles are also the main source of roadside air pollution. To help address these serious issues, the Government set up a HKD300 million Pilot Green Transport Fund designed to encourage public transport trades, goods vehicle operators and charitable and non-profit-making organisations to try out innovative green and low-carbon transport technologies, including the use of EVs.

The Fund has an upper limit of HKD12 million per transport operator. Applicants can submit more than one application to try out different technologies, like hybrid vehicles and pure EVs or to try the same technology from different suppliers. Table 2-2 and Table 2-3 shows applications to the Pilot Green Transport Fund that have been approved by the Environmental Protection Department (EPD)[39].

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37 *Environmental Protection Department, Promotion of Electric Vehicles in Hong Kong, retrieved from https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/promotion_ev.html*

38 *Environmental Protection Department, Pilot Green Transport Fund, retrieved from https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/pilot_green_transport_fund.html*

39 *Environmental Protection Department, The Number of Applications Approved and the Limit of Applications for Electric Vehicles, Dec 2019, retrieved from http://www.epd.gov.hk/epd/sites/default/files/epd/english/environmentinhk/air/prob_solutions/files/No_of_App_and_Prod_Approved.pdf*

Vehicle Class	Permitted Gross Vehicle Weight [W] tonnes	Number of Applications Approved	Number of Products Approved
Light goods vehicle	W ≦ 5.5	91	128
Medium goods vehicle	5.5 < W ≦ 10	-	-
	10 < W ≦ 13	-	-
	13 < W ≦ 16	1	1
	16 < W ≦ 24	-	-
Heavy goods vehicle	24 < W	-	-
Non-franchised bus with 17 to 30 seats		-	-
Non-franchised bus with 31 seats and above		13	21
Franchised public bus, single deck		-	-
Franchised public bus, double deck		-	-
Light bus		2	3
Taxi		3	3
Total		110	156

Table 2-2 Summary of the number of applications and products in the Pilot Green Transport Fund - Electric Vehicle

Vehicle Class	Permitted Gross Vehicle Weight [W] tonnes	Number of Applications Approved	Number of Products Approved
Light goods vehicle	W ≦ 5.5	30	48
Medium goods vehicle	5.5 < W ≦ 10	15	27
	10 < W ≦ 13	-	-
	13 < W ≦ 16	-	-
	16 < W ≦ 24	-	-
Heavy goods vehicle	24 < W	-	-
Non-franchised bus with 17 to 30 seats		-	-
Non-franchised bus with 31 seats and above		2	2
Franchised public bus, single deck		-	-
Franchised public bus, double deck		-	-
Light bus		18	20
Taxi		-	-
Total		65	97

Table 2-3 Summary of the number of applications and products in the Pilot Green Transport Fund - Hybrid Vehicle

2.5.4 Trial run of electric franchised buses

In addition to the incentives mentioned above, the HKSAR Government allocated HKD180 million to allow five franchised bus companies to purchase 36 single-decker electric buses, including 28 battery-electric buses and 8 super capacitor buses, for trial runs to assess their operational efficiency and performance under local conditions. By December 2018, 26 battery-electric buses and 4 super capacitor buses have commenced operations. The first phase of the trial scheme was completed in May, with five battery-electric buses tested. The stated range of these buses was around 190km, however in hot weather, when the buses' air conditioning systems were fully loaded, the range dropped down to around 150km only. Considering the daily driving range of a bus is from 200km to 300km, it means that these current models could not fulfill the operational needs of the bus companies[40]. The trial of two super capacitor buses is still going on. The remaining ten electric buses are expected to be progressively put into service, with the overall objective being to have several zero emission buses running in Hong Kong.

2.6 Type approval

2.6.1 Review of current type approval procedures

The type approval procedures for EVs remain unchanged. EV drivers need to submit their documents to the Transport Department and wait for an appointment for a vehicle examination when obtaining type approval. Further details of the procedures can be found in the "Type Approval Requirements for Electric Vehicles" document issued by the Vehicle Safety and Standards Division of the Transport Department.[41]

2.6.2 Approved EV models in Hong Kong

As at end of December 2019, there are 13,866 EVs for road use, up from less than 100 in end 2010. At present, 105 EV models from 10 economies have been type-approved by the Transport Department. These include 76 models for private cars and motorcycles, 29 models for public transport and commercial vehicles, listed as follows: [42]

Vehicle Classification	Name of Retailer	Model
Private car		Euauto MyCar
Private car	Universal Cars Limited	Mitsubishi iMiEV
Private car	Honest Motors Limited	Nissan LEAF Nissan LEAF Plus Nissan LEAF Lux Nissan E-NV200 5-seater Nissan E-NV200 7-seater Nissan E-NV200 EVALIA 5-seater Nissan E-NV200 EVALIA 7-seater
Private car	Tesla Motors HK Limited	Tesla Model 3 Performance Dual Motor Standard Range Tesla Model S 85 kWh Performance 85 kWh 60 kWh 70 kWh Dual Motor 85 kWh Performance Dual Motor 85 kWh Dual Motor 90 kWh Dual Motor 90 kWh Performance Dual Motor 70 kWh 90 kWh 75 kWh Dual Motor 75 kWh 60 kWh Dual Motor 100 kWh Performance Dual Motor 100 kWh Dual Motor

40 *The Government of the HKSAR, Press release, Dec 2018, retrieved from https://www.info.gov.hk/gia/general/201812/12/P2018121200667.htm*

41 *Vehicle Safety and Standards Division, Type Approval Requirements for Electric Vehicles, Nov 2010, retrieved from http://www.td.gov.hk/filemanager/en/content_1178/ta_req_ev_eng.pdf*

42 *Environmental Protection Department, EV Models in Hong Kong, retrieved from https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/promotion_ev.html#EV_Models_HK*

Vehicle Classification	Name of Retailer	Model
		Tesla Roadster Tesla Model X 60 kWh Dual Motor 75 kWh Dual Motor 90 kWh Dual Motor 90 kWh Performance Dual Motor 100 kWh Performance Dual Motor 100 kWh Dual Motor Long Range
Private car	BMW Concessionaires (HK) Limited	BMW i3 (I01) BMW i3 94AH(I01) BMW i3s 94AH(I01) BMW i3 120AH(I01) BMW i3s 120AH(I01)
Private car	Wearnes Motors (HK) Limited	Renault Fluence Z.E. Renault ZOE Renault ZOE (16 Alloy Wheel) Renault ZOE (R240) Renault ZOE (Q210) Renault ZOE (ZE40) Renault ZOE (ZE40)(BOSE)
Private car	BYD (H.K.) Co., Ltd.	BYD e6
Private car	Fortune Dragon Motors Limited	TAZZARI “EM1”
Private cars	Mercedes-Benz Hong Kong Limited	Smart Fortwo Coupe Electric Drive (C453) Smart Forfour Electric Drive (W453)
Private car	Volkswagen Group Hong Kong Limited	Volkswagen e-GOLF 85kW 24.2kWh CL New e-Golf
Private car	Hyundai Hong Kong Co., Ltd	Hyundai Ioniq Electric Hyundai Kona Electric Hyundai Kona Electric (Urban) Hyundai Kona Electric Range+ Hyundai Kona Electric Range+ (Urban)
Private car	British Motors Limited	Jaguar I-PACE EV400 Jaguar I-PACE EV400 S Jaguar I-PACE EV400 SE Jaguar I-PACE EV400 HSE
Private car	KIA Motors (Hong Kong) Ltd.	KIA Niro EV+ Deluxe KIA Niro EV+ KIA Niro EV
Motorcycle		Brammo Enertia Brammo Enertia Plus Brammo Empulse Brammo Empulse R E-MAX "120LD+" Vectrix Scooter VX-1
Motorcycle	GMI	GMI Proton 750 GMI Proton 850

Vehicle Classification	Name of Retailer	Model
Motorcycle	Zero Motorcycles Hong Kong	Zero S (ZF9) Zero S ZF11.4 Zero SR ZF11.4 Zero S ZF13.0
Light goods vehicle	Fortune Dragon Motors Limited	Micro-vett electric Doblo (based on Fiat Doblo)
Light goods vehicle	Wearnes Motors (HK) Limited	Renault Kangoo Van Z.E. Renault Kangoo Van Z.E. 2-seater Renault Kangoo Van Z.E. 5-seater Renault Kangoo Z.E. 33
Light goods vehicle	Universal Cars Limited	Mitsubishi Minicab-MiEV
Light goods vehicle	Honest Motors Limited	Nissan E-NV200 Half Panel Van (LGV) Nissan E-NV200 Full Panel Van (LGV)
Light goods vehicle	Vasplex Motor Co., Ltd.	DFSK EC35
Light goods vehicle	Heng Chang Vehicle	JOYLONG EW4 JOYLONG EW5
Light goods vehicles	E. Tech Dynamic Technology Co., LTD.	FAW VERTEC
Medium goods vehicles	BYD (H.K.) Co.,Ltd.	BYD Q1
Light bus	Confidence Motors Limited	Wuzhoulong FDG6700EVG
Light bus	Regal Motors Limited	King Long XMQ6706CYBEVS
Bus	BYD (H.K.) Co., Ltd.	BYD K9D K9R C9 C9R
Bus	Great Dragon International Corp. Ltd.	Shandong Yixing HC-150-120 (Great Dragon) HC-150-105 (Feiyan) LS-150-105 LS-130-116
Bus	China Dynamics (Holdings) Limited	Suitong YST6120BEV
Bus	Confidence Motors Limited	Wuzhoulong FDG6102EVG FDG6110EV2
Bus	Regal Motors Limited	Youngman "JNP6122UC" ultra capacitor bus
Bus	China Green Dynamics Co., Ltd.	China Green Dynamics EFV3000
Taxi	BYD (H.K.) Co., Ltd.	BYD e6

2.7 Views and recommendations

2.7.1 Invest more effort in promoting EVs for commercial use

Commercial vehicles like goods vehicles, franchised and non-franchised buses and taxis are the major source of roadside emissions in Hong Kong. Roadside emissions reduction initiatives will become much more effective if these commercial vehicles were powered by electricity instead of internal combustion engines.

Recommendation 1: Offer incentives and special programmes for commercial fleets
Vehicle pollution is a significant factor in any developed and populated city. In Hong Kong, emissions from diesel-powered commercial vehicles including trucks, buses and public light buses produce large amounts of airborne particles and nitrogen oxides. In crowded urban environments with busy roads, pollutants trapped at street level can increase the ambient temperature and produce significant health implications. Similar to existing initiatives in London and Beijing, the policy makers should consider targeting commercial fleets for expanding EV numbers in the city.

Commercial fleets such as franchised buses are suitable targets for electric vehicle or hybrid electric vehicle adoption schemes. Replacing diesel-powered vehicles with EVs will appreciably reduce airborne particles and nitrogen oxides at street level. Locally, there are only three bus company operators, meaning it would be relatively easy to manage EV adoption using a phase-in plan when renewing contracts.

Similarly, taxis, public minibuses and other types of commercial vehicle fleets can also develop phase-in plans to guide fleet replacement, allowing any new replacements to be electric vehicles. EVs are a new class of vehicle, and many new technologies are being developed related to EVs. Commercial fleet operators can also be encouraged to adopt such new technologies as battery swapping, wireless charging and super capacitors. These technologies could be trialled with Government support when they become mature enough for the public trial phase.

Recommendation 2: Provide high power charging facilities
Similar to franchised buses and public light buses, the operational time of commercial vehicles is normally in excess of 12 hours per day. Schedules must be strictly adhered to, in order to fulfil the needs and expectations of passengers. Taxi operators have similar operational requirements. Being in operation for so long leaves very limited time for charging, and operators and drivers cannot afford a medium charging time of three hours. Thus, high power charging facilities with minimum of 200kW should be provided which can charge electric commercial vehicle batteries within 30 minutes.

Recommendation 3: Develop commercial EVs meet the needs of Hong Kong
As at end of December 2019, there are 13,866 EVs for road use, up from less than 100 in end 2010. At present, 105 EV models from 10 economies have been type-approved by the Transport Department. These include 76 models for private cars and motorcycles, 29 models for public transport and commercial vehicles[43]. There was only one medium-duty vehicle model and there were no approved models of heavy-duty vehicles or special purpose vehicles like crane lorries, tankers, dump trucks, tractors, refuse collection vehicles and others. As of November 2019, the total registered number of these three vehicle types – medium-duty, heavy-duty and special purpose – was more than 45,000[44]. Local R&D centres could collaborate with Mainland China or overseas vehicle manufacturers to develop tailor-made medium-duty vehicles and heavy-duty vehicles which meet the operational needs and traffic conditions of Hong Kong.

2.7.2 Strengthen and target government incentives for private EV adoption
Governments often play an active role in promoting and encouraging private EV adoption. This fact is evident from observations made in several other countries.

Recommendation 4: Provide infrastructure support for private EVs
The policy makers should consider strengthening their promotion and augmentation of the deployment of EVSE. This can be achieved through incentive programmes, tax concessions and pilot programmes, similar to other markets. Hong Kong needs a strategic vision in terms of EV infrastructure support.

While the number of privately owned EVs is steadily rising, the promotion of private EVs is mostly – and rightfully – performed by car vendors in a similar manner to the promotion of gasoline powered cars. As in the case in other markets, the policy makers can provide support and facilitate the setup of EV-related infrastructure and charging points for private EVs. While high-speed chargers have the advantage of being able to charge EVs in under 30 minutes, they are expensive to set up. As such, an optimal proper mix of EV chargers should include both medium- and high-speed chargers, while slower chargers will be slowly phased out. Charging infrastructure will be discussed in details in the next chapter.

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43 Environmental Protection Department, EV models in Hong Kong, retrieved from https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/promotion_ev.html#EV_Models_HK

44 Table 4.4 : Registration and Licensing of Vehicles by Fuel Type (November 2019), retrieved from https://www.td.gov.hk/filemanager/en/content_4900/table44.pdf

CHAPTER 3: CHARGING INFRASTRUCTURE

3.1 EV charging development in Hong Kong

Over the past few years, stakeholders in the EV charging industry have been more proactive in contributing to the expansion of the EV charging network and supporting the rapid growth of EVs in Hong Kong. In 2014, we proposed six recommendations for EV charging development strategies. Some of these recommendations have been adopted by the industry while the others are still in the early stages of development. In this section, we will review the implementation progress of each recommendation.

(1) Our recommendation in 2014	Create a common set of standards for all levels of EV chargers in Hong Kong

"To promote the wider adoption of private EVs, it is recommended that the HKSAR government consider defining the charging standards for all levels of EV chargers and making these charging standards a part of the type approval processes."

Latest update	Create a common standard for medium chargers and keep the multi-standard for quick chargers

We have observed that the majority of medium chargers that have been installed in recent years are of IEC Type 2 standard, which are used by European EVs. These chargers do not pose any obstacles to US and Japanese EVs, as these vehicles can use a simple conversion cable (SAE J1772 to IEC Type 2) when charging, thanks to a compatible communication protocol between those two standards. Although early Tesla EVs employ a proprietary charging standard, all Tesla EVs sold in Hong Kong in recent years are equipped with IEC Type 2 sockets.

However, an internationally harmonised standard for quick charging has yet to be developed. There are several standards currently in existence, including the Japanese CHAdeMO, the European and American Combined Charging System (CCS), the European IEC Type 2 AC 3 Phase, and the Chinese Guobiao (GB) – and none of these are compatible with one another. In a recent market development, EV charger manufacturers have launched a number of multi-standard products to enhance the versatility of EV chargers. The most common multi-standard quick chargers installed in Hong Kong support CHAdeMO, CCS, and IEC Type 2 AC 3 Phase; while the GB standard quick chargers in Hong Kong are all dedicated chargers only.

(2) Our recommendation in 2014	Migrate EV charging infrastructure to medium and quick chargers

"The HKSAR Government and EV charging operators are recommended to consider migrating existing slow charging Level 1 standard chargers to medium and quick chargers to cater for new-generation EVs."

Latest update	Continuous upgrading of EV chargers

To enhance the efficiency of public charging facilities, the HKSAR Government has been both upgrading and increasing the number of public chargers at government car parks managed by the Transport Department and the Government Property Agency over time. In 2014, the EPD upgraded 100 standard chargers to medium chargers, while in 2017, the EPD upgraded 170 standard chargers to medium chargers.

The two power companies and the commercial sector have also been progressively upgrading their existing public standard chargers to medium chargers and installing multi-standard quick chargers that support CHAdeMO, CCS, and IEC Type 2 AC 3 Phase.

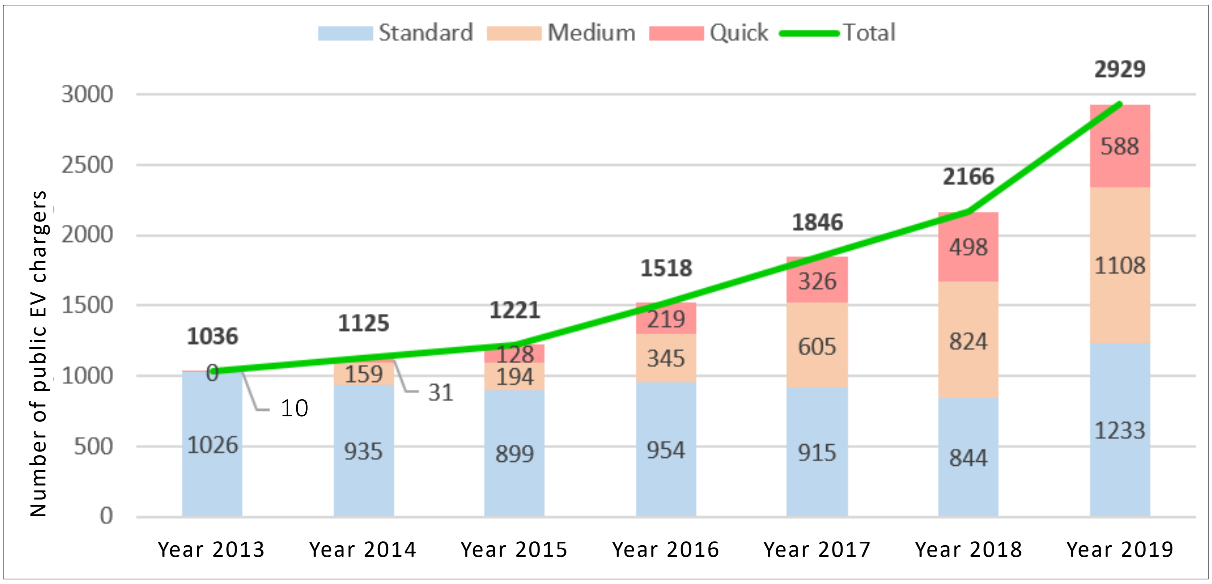

Figure 3-1 Evolution of public EV chargers in Hong Kong[45]

Figure 3-1 illustrates the number of public EV charging points in Hong Kong from 2013 to 2019. These public chargers were built by the HKSAR Government, the two power companies and the private sector, and that they are located in the car parks of government buildings, public estates, shopping malls and other facilities. The figure clearly shows that the number of medium chargers and quick chargers are growing, while the number of less practical standard chargers is gradually decreasing.

(3) Our recommendation in 2014	Set up a centralised database of EV charging points

"A centralised database of available EVSE can be set up and maintained, either by the Government or a neutral third party, to provide information to EV drivers on the status of EVSE and their locations."

Latest update	More data is being provided through apps, while newer EVSE can deliver real-time status and availability information

45 *Environmental Protection Department, Promotion of Electric Vehicles in Hong Kong, retrieved from http://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/promotion_ev.html*

Through mobile or web applications, EV charging service providers are broadcasting general information about their charging facilities, for example their location and their charging standard. Although this is not the case for all chargers, it is more common to find newly-installed EV chargers that have Internet of Things (IoT) capability – i.e. they can provide real-time information such as their status and availability for EV users. Figure 3-2 and Figure 3-3 show an EV charging station map for CLP and Hong Kong Electric (HK Electric).

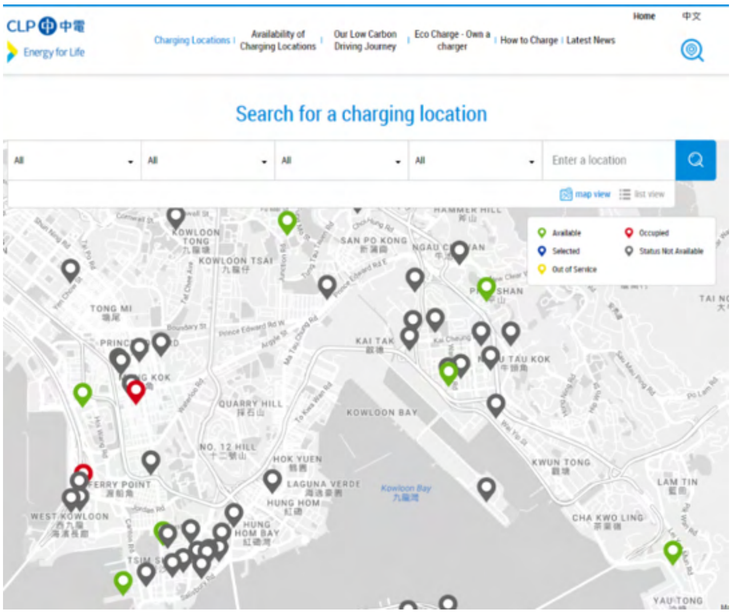

Figure 3-2 Charging location map of CLP facilities[46]

Figure 3-3 Charging location map of HK Electric facilities[47]

However, there is still no common platform that shares information among the service providers. In other words, EV users can only use a dedicated mobile app to find the real-time information of a particular service provider – the apps do not provide information on other service providers' facilities.

The EV industry has not taken full advantage of the Government's well-established public sector information portal – data.gov.hk – to share data. In terms of EV charging information, only CLP and HK Electric share information, with CLP providing XML format files[48] for location data (including the GPS coordinates and addresses) of electric vehicle charging stations; while HK Electric provides CSV files[49] which contain the car park name, district, address, level/floor, parking bay number, service provided and the GPS data of their charging stations.

(4) Our recommendation in 2014	Develop a viable business model for electricity supply to EV charging services

"This study recommends that EVSE service providers develop a sustainable business model with property developers, property management companies and power companies. If needed, the Government can play a role in helping these players work together in mutually-beneficial arrangements."

Latest update	The EV charging business is growing, with the provision of more diversified services

46 *CLP, Charging Locations, 2017, retrieved from https://services.clp.com.hk/ev/en/charginglocations.html*
47 *Hong Kong Electric, Charging Locations, 2017, retrieved from http://minisite.hkelectric.com/electricvehicles/charging_stations1.html*
48 *data.gov.hk, CLP Electric Vehicle Charging Station Locations, 2017, retrieved from https://data.gov.hk/en-data/dataset/clp-team1-electric-vehicle-charging-location*
49 *data.gov.hk, details of HK Electric EV Charging Stations, 2017, retrieved from https://data.gov.hk/en-data/dataset/hkelectric-tnd_cs_ci-hkelectric-ev-location*

In recent years, more private companies are providing one-stop EV charging services, including the installation of charging facilities and the provision of charging services in both public and private car parks of housing estates and private premises.

One business model is the "Buy and Own" model, where a site host purchases all relevant equipment from an EV charging service provider, equipment which the site host then owns. The service provider is responsible for operating and maintaining the charging infrastructure. The site host can decide to provide a free or paid charging service. The other model is the "Subscription" model, with the service usually targeting private car parks. The EV charger service provider builds the charging infrastructure at its own cost, then the users of these car parks use the EV charging services in their private parking spaces by subscribing to suitable monthly service plans.

These business models allow the private sector to provide sustainable EV charging services, to grow these services, and to take on more responsibility for developing the EV charging infrastructure in Hong Kong.

(5) Our recommendation in 2014	Install power load management systems in existing car parks

"It is recommended that EV charger operators and property management companies investigate the use of intelligent electricity load management systems in order to meet the overall demand for extra EV chargers without needing to increase electricity supply loading in existing car parks."

Latest update	The growing demand for EV chargers will soon boost the importance of load management technology

The provision of sufficient charging facilities is crucial to the adoption and continued use of EVs. Load management technology can analyse and regulate the power usage of each EV charger in real time so that EVs can efficiently share the available electric power supply in a given charging station. Load management technology offers a smart, economical and viable solution to install more EV chargers in an area with limited power supply.

In Hong Kong, a few charging service providers, charger manufacturers and research institutes have started to provide load management solutions. Although the technology is still in the pilot or small-scale implementation phase, it is foreseen that load management technology will soon become important as the demand for EV chargers grows.

(6) Our recommendation in 2014	Install more EV chargers in private residential buildings and commercial sites with government support

"The HKSAR Government is recommended to consider augmenting its support for setting up EV chargers in residential buildings and power supply infrastructure at commercial sites. This support may be achieved through the extension of the Green Transport Fund to cover the setup costs of EV chargers."

Latest update	Greater acceptance due to collaboration between the Government and the private sector

The HKSAR Government continues to encourage developers and property management companies to facilitate the setup of chargers at existing private residential buildings and install more chargers in commercial premises. Beginning in 2011, gross floor area concessions have been granted for car parks in new buildings; these concessions have been extended in phases, so as to encourage developers to put in place the necessary EV charging infrastructure – including providing sufficient power supply, cables and ducts – in the buildings concerned. The Chief Executive announced in the 2019 Policy Address that the Government will prepare for a $2 billion pilot subsidy scheme to subsidise installation of EV charging-enabling infrastructure in the car parks of the existing private residential buildings.

The Government continues to collaborate with the property management sector, incorporated owners, owners' committees, the two power companies and charging service providers to organise seminars where stakeholders can share the latest developments, information on the newest charger installation technologies and their successful experiences, with a view to encouraging developers and property management companies to install chargers in more housing estates.

The two power companies have also launched a one-stop service to provide technical support to EV owners who intend to install charging facilities in the parking spaces in residential or commercial buildings. For instance, Hong Kong Electric launched an online tool called "Smart EV Charge Easy Online Advisor" in September 2016. After answering some simple questions, the online advisor will provide a tailor-made preliminary proposal for EV owners, incorporated owners or management offices. CLP offers a similar service with its "Eco Charge Electric Vehicle Power Supply Support", a one-stop service which supports EV users as they install EV chargers.

At the same time, some private companies in the market are providing one-stop EV charging services, which sees the companies investing in full charging facilities for private car parks at residential sites, and then providing charging services via a paid subscription plan. One-stop solutions like these can relieve the lingering concerns of incorporated owners and owners' committees.

3.2 Industry views

Apart from reviewing the changes over the past few years, for this study we interviewed a number of EV charging service providers, EV manufacturers and distributors, and EV associations to qualitatively capture their views on the current EV charging development situation in Hong Kong. A total of 11 parties were interviewed in February and March 2017. Table 3-1 lists the companies and organisations were interviewed. Their views are summarised below.

Category	Interviewee
EV Charging Service Provider	Autotoll
	CLP Power
	HK Electric
	Hong Kong EV Power Limited
	i-Charge Solutions International Co. Ltd.
	Smart Charge (HK) Limited
EV Manufacturer / Distributor	BMW Concessionaires (HK) Ltd
	Tesla Motors HK Limited
	Dah Chon Hong (Nissan's dealer)
EV Association / Club	Charged Hong Kong (The Hong Kong Electric Vehicle Association)
	Electric Vehicle Club Hong Kong

Table 3-1 List of survey interviewees

Views on the development of the EV market:
The interviewees believed that the growth in EV numbers in Hong Kong would slow down in 2017 due to changes in the FRT concession policy. Despite this, most of them were positive about the long-term future of EVs in Hong Kong. The main reasons included:
- It is a global trend
- More affordable and longer-range EV models are becoming available

Views on the challenges inherent in building EV charging infrastructure:
The participating EV charging service providers expressed the view that the sustainability of charging service businesses (i.e. paid charging services) is in doubt, since the majority of public charging services are free. Some interviewees stated that although some incorporated owners are still hesitant to invest in or approve the installation of EV chargers, the situation is gradually improving as public awareness of EVs has grown over the past few years. In terms of technical challenges, some car parks lack sufficient electric power capacity to install more EV chargers. Some interviewees suggested that selecting a single standard for quick charging may reduce the initial investment costs, while others said that both CHAdeMO and CCS will still be needed in the near future.

Views on catering for future EV charging infrastructure demand
The interviewees generally thought that upgrading standard chargers to medium or quick chargers is the correct direction in which to proceed. Apart from these upgrades, there is a need to install more DC quick chargers for public use, particularly in the New Territories. Most of the interviewees agreed that a centralised data platform is critical for sharing EV charging data such as the real-time status of individual charging units – this will allow stakeholders to tailor their products and services to EV users more effectively, and EV users will have a more convenient charging experience. In addition, the establishment of a neutral industry association comprised of members from stakeholder groups will help drive the development of the industry and share the technology and engineering perspective with the Government.

Some interviewees suggested that providing education programmes and brochures to the public and other stakeholders may help relieve their concerns about installing EV chargers. On the other hand, a few interviewees suggested that curb-side or street charging facilities would help broaden the EV charging infrastructure network.

Apart from these interviews, two recent surveys explored the views of the general public and EV owners from other angles. These surveys are the “Best Practices and Strategies for Low-Carbon Urban Transport System”, conducted by the Chinese University of Hong Kong, and the “Behavioural Studies of EV owners” conducted by Electrify Hong Kong, another Hong Kong-based EV association. The consent of both parties was obtained to cite their results in this study.

In July 2016, the Institute of Future Cities at the Chinese University of Hong Kong disseminated the results of a research project called “Best Practices and Strategies for Low-Carbon Urban Transport Systems”[50]. A research team led by Professor Leung Yee, director of the Institute, conducted a comprehensive study of low-carbon transport practices and policies with the objective of formulating a strategy for future Hong Kong low-carbon transport systems. In a chapter called “Sustainable Transport Modes: Electric Vehicles”, 602 people took part in a telephone survey. Some of the findings are listed below:

- The three most important strategies to influence the public’s willingness to buy an EV are:
  i) shorter recharging times,
  ii) more charging stations, and
  iii) the ability to reserve parking spaces.

50 *The Chinese University of Hong Kong, Best Practices and Strategies for a Low-Carbon Urban Transport System, 2016, retrieved from http://www.iofc.cuhk.edu.hk/low-carbon-transport*

- Over 70% of the public are willing to drive a maximum of 15 minutes to a charging station
- Almost 80% of the respondents said that a maximum of one hour was an acceptable charging time
- The presence of more charging stations would influence the respondents to buy an EV (63.7% either agreed or strongly agreed)

According to the "Report on a Study of Road Traffic Congestion in Hong Kong",[51] published by the Transport Advisory Committee in 2014, the average speed of traffic across Hong Kong during the morning peak hours on weekdays is about 20km/h (see Figure 3-4). Assuming an average driving speed of 20km/h, a 15-minute drive is equivalent to about five kilometres. Based on this assumption, one can plan the potential spatial distribution of EV charging stations. Spatial distribution is an important consideration in developing EV charging strategies in other markets. For instance, the Chinese Government is targeted a public charger service radius of between 0.9 km and 2km in major cities[52].

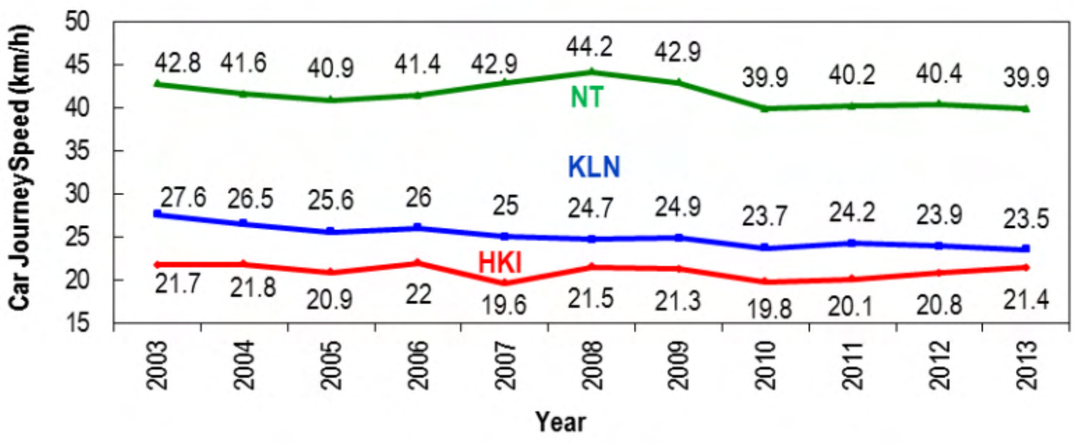

Figure 3-4 Car journey speeds during morning peak hours on weekdays in Hong Kong (2003 – 2013)

Although the UK Government has not sent any comparable targets, it provides statistic data on the average distance to the nearest public charger[53]. This was 6.58km as of January 2016. Therefore, a five kilometre radius seems to be a reasonable distance when compared with other markets; of course, the target distance to the nearest charger in each district of Hong Kong should be set based on the existing situation in that district.

Electrify Hong Kong is a new association which was established in 2017. They recently conducted an internal survey of their members called "Behavioural Studies of EV Owners". The survey gained 82 total responses, 79 of whom were EV owners. The results can be consolidated as follows:

- More than 67% of EV owners cannot charge their EVs at their homes, and are thus reliant on public EV charging stations.
- About 70% of the respondents believed that difficulties encountered in installing private EV chargers are related to the decisions made by property management offices, owners' committees, parking lot owners and owners' corporations.

51 *Transport Advisory Committee, Report on a Study of Road Traffic Congestion in Hong Kong, 2014, retrieved from http://www.thb.gov.hk/eng/boards/transport/land/Full_Eng_C_cover.pdf*

52 *National Energy Administration, 電動汽車充電基礎設施發展指南(2015-2020), 2015, retrieved from http://www.nea.gov.cn/134828653_14478160183541n.pdf*

53 *Element Energy Ltd, Transport Energy Infrastructure Roadmap to 2050, 2015, retrieved from http://www.element-energy.co.uk/2015/06/transport-energy-infrastructure-roadmaps-published/*

These findings are consistent with practical challenges encountered by HK Electric, who shared their support for EV development in "A Joint Seminar on Setting Up Electric Vehicle (EV) Chargers in Existing Private Residential and Commercial Buildings", published in 2015, which noted that the main challenge to providing charging facilities in existing buildings is obtaining agreement from the incorporated owners, rather than the associated costs. Therefore, installing home chargers is not a problem that can be simply solved by providing subsidies. Better coordination and more education are also important components.

3.3 Overseas experiences

3.3.1 Industrial platforms

These days, it is quite common to find associations or industrial platforms formed by stakeholders that work together to harmonise common targets, goals and strategies for developing EV charging networks around the world. These stakeholders include governments, power companies, charging service providers, property management offices, universities, R&D institutes, EV user groups, building owner groups and more. Below are several examples of these platforms from the US, Mainland China and Germany.

US – ROEV Association	ROEV Association is an EV industry trade association created to increase the appeal of EVs by enabling charging network interoperability in the US. This neutral collaboration of industry stakeholders was founded by BMW, CarCharging/ Blink, ChargePoint, EVgo and Nissan. The association provides accessible and convenient public charging for EVs in the US by enabling drivers to charge across multiple charging stations and networks, using any participating EV charging network account.
Mainland China – China Electric Vehicle Charging infrastructure Promotion Alliance	The China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA) was established on October 2015 and is located in Beijing. The alliance is a non-profit organisation which coordinates stakeholders in development strategies for the EV charging infrastructure in Mainland China. EVCIPA's members include the major domestic EV automakers, power companies, telecommunications service providers, EV charger manufacturers and EV charging services. EVCIPA is led by the National Energy Administration of the Chinese government.
Germany - German National Platform for Electric Mobility	The German National Platform for Electric Mobility (NPE) orchestrates the development of electric mobility in Germany. It is an advisory body to the Federal Government, bringing together 150 representatives from industry, science, politics, trade unions and trade associations for strategic dialogue. Collectively, they investigate the economic, social and environmental potential of electric mobility and recommend actions for politicians and businesses. The NPE has a specific working group (WG3) which focuses on charging infrastructure and power grid integration.

Collaboration among stakeholders can harmonise common goals for EV charging network development and facilitate more effective implementation of development strategies; and can also help avoid stakeholders make investments in directions that may not be fully accepted by the industry. Establishing an industrial platform or association can also encourage data sharing among members, which can create more innovative businesses and services.

3.3.2 Engagement of the private sector

Most of the markets looked at by this study accept that home charging is the most suitable everyday charging mode for EV users. The next option is to install EV chargers in workplaces or semi-public locations. The use of public EV chargers is the final option for those without home chargers, or to be used for opportunity charging. As Mainland China is the world's largest EV market, the Chinese Government announced a strategy called "Guidelines for Developing Electric Vehicle Charging Infrastructure (2015– 2020)" under the China's 13th Five-Year Plan which, setting a mission of exploring sustainable business models, encourages private companies to become more involved and take up more responsibility for public and private charger infrastructure expansion – rather than relying on the government's resources alone. As such, the Chinese Government has targeted developing 500,000 public chargers and 4,300,000 private chargers to cater to a demand equivalent to 5,000,000 EVs by 2020. Similarly, in 2016, the US Government announced that it would unlock up to USD4.5 billion in loan guarantees and invite applications to support the commercial-scale deployment of innovative EV charging facilities. These large-scale, ambitious strategies prove that the private sector is destined to play a crucial role in the development of EV charging.

3.3.3 Emerging technologies

A number of innovative EV charging technologies and solutions are emerging, and governments around the world are keen to put these technologies to work to create benefits for the public. In Federal action announced in the US, the government is laying the groundwork for big data analytics to inspire new EV charging solutions. In the Netherlands, a programme called "Living Lab Smart Charging" has been established; this is an open platform that allows companies, universities, local and regional governments and grid operators to cooperate. Below, we will briefly introduce some EV charging technologies show promise in the near-term.

Wireless charging

Wireless Electric Vehicle Charger (WEVC) is seen as a key enabling technology that can increase the EV adoption rate by providing a convenient and easy-to-use charging experience to users. WEVC transmits electrical energy from a transmitter coil on the ground to a receiver coil on an EV chassis through a highly-efficient energy transfer. SAE J2954 is to be tested in the next two years by vehicle automakers and was standardised at the end of 2018. This standardisation milestone was given by the industry to enable the commercialisation of wireless power transfers of up to 11kW by 2020.

Smart power distribution (also known as load management)

While EV penetration rates continue to rise and more EV charging facilities are built, the electrical systems (low-voltage distribution) in residential or commercial buildings may face the risk of overloading power lines and transformers and creating voltage drops.

As illustrated in the "Global EV Outlook 2017" publication, charging facilities can be scaled up in phases that follow the growth in EV numbers. Smart charging is needed at EV charging stations to ensure that the available power is shared among all the chargers at the station. In the third phase proposed in the publication, which sees a high demand for EV charging, the idea of smart charging is extended to the building level – this means that the available power in the entire building needs to be distributed between all the apartments in the building and the EV charging station.

In Norway, the Innovative Charging Facility[54] has been built in Oslo, the capital city. The facility consists of two fast chargers with up to 50kW of charging power and 100 flex chargers that provide up to 22kW of charging power. At night, residents of the area park and charge for free at a rate of 3.6kW. During the daytime, regular parking fees applies and the opportunity to choose faster charging is offered for a fee. A unique battery solution balances phase distortions and reduce peaks in the power grid. This means that EVs get more power at every charge point.

In the Netherlands's "Living Lab Smart Charging" programme, all new charging stations that are currently being installed are 'smart charging ready', using proven standards. The Living Lab turns innovation, tests and research findings into international standards so that everyone can benefit from their smart charging experiences. For instance, one programme sees EV users earn money by charging their vehicles through wind power at night.

Mobile EV chargers

Mobile EV charger break free of the limitations of ordinary charging facilities, which for obvious reasons are required to stay in fixed locations. Mobile chargers can help provide flexible charging services to EVs when charging stations are not available. They can also provide emergency charging services for battery-drained EVs on the road.

High-power charging

In recent years, EV industry technology is trending towards using high power charging, also known as ultra-fast charging, which increases the charging power from 150kW to 450kW; making the charging speed between three and nine times faster than existing 50kW quick chargers. With charging speeds that fast, the charging experience will be similar to refuelling at a gas station. The Charging Interface Initiative e.V. (CharIN e.V.) predicts that a driving range of 100km will be topped up within four minutes using 350kW high power charging for a private EV, as illustrated in Figure 3-5.

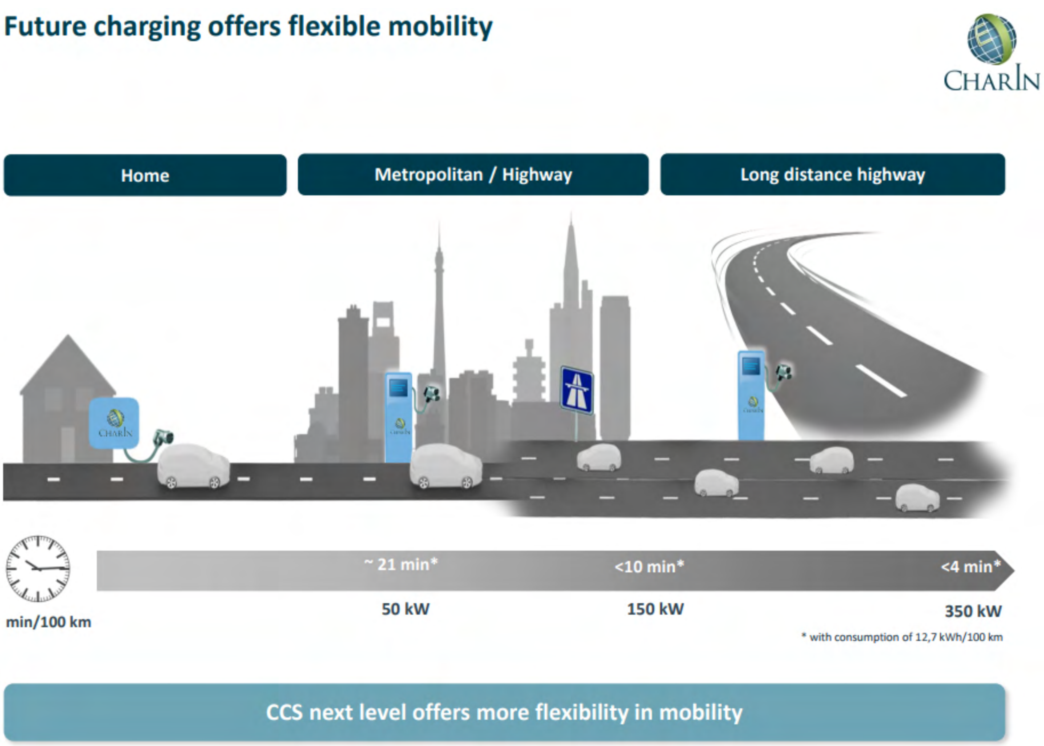

Figure 3-5 Future charging practices by CharIN e.V[55]

54 *Fortum, Fortum Charge & Drive opens an innovative charging facility for electric vehicles in Oslo, Norway, 2016, retrieved from https://www.fortum.com/media/2017/11/innovative-charging-facility-electric-vehicles-oslo-norway*

55 *CharIN e.V., The path to a global charging standard, 2017, retrieved from http://www.charinev.org/fileadmin/Downloads/Presentations/2017_CharIN_Charge_Days_Bracklo.pdf*

The Charging Interface Initiative e.V. is the major industrial promoter of high-power charging. CharIN e.V. is a registered association founded by Audi, BMW, Daimler, Mennekes, Opel, Phoenix Contact, Porsche, TÜV SÜD and Volkswagen. The members of CharIN e.V. span the entire supply chain of the EV charging industry and include EV manufacturers, EV charger manufacturers, service providers, charging cable manufacturers, semiconductor suppliers, testing equipment suppliers, and testing and certification bodies.

In November 2017, the BMW Group, Daimler AG, the Ford Motor Company and the Volkswagen Group, along with Audi and Porsche announced a joint venture called IONITY, which aims to develop and implement a High-Power Charging (HPC) network for EVs across Europe[56]. Approximately 400 high power charging stations will be built by 2020 which offer multi-brand compatibility with current and future generations of EVs through the Combined Charging System (CCS). On the other side of the Atlantic, Electrify America will deploy 2,000 350kW CCS fast chargers across the US by the end of 2019.

Apart from the European and US CCS standard, the CHAdeMO Association in Japan released the latest protocol version of the CHAdeMO standard to support high-power charging up to 400kW. These plans and actions reveal the industry's future high-power charging ambitions.

Interoperability within EV charging networks

With IoT-compatible and interoperable charging platforms, EV users can charge easily, access real-time information about individual chargers and pay at any charging station. An interoperable EV charging network makes barrier-free electric mobility possible. In the US, the ROEV Association is a neutral collaboration of industry stakeholders designed to support EV adoption by facilitating public charging network interoperability. Its founding members are BMW of North America, Nissan, ChargePoint, NRG EVgo, and CarCharging/Blink. The Association's platform allows EV users to easily check information and access most public EV charging stations across multiple networks using one network account.

In the industry, the Open Charge Point Protocol (OCPP), a communication protocol, is gaining a significant amount of attention at the moment. The OCPP was developed by the Open Charge Alliance (OCA) and is a universal open solution for communications between EV chargers and any central system. With the OCPP, charging service providers can operate different brands of EV chargers, as long as they use the same communication protocol.

In addition to the OCPP, in Europe, the concept of eRoaming is currently being promoted. eRoaming platforms enable users to charge their vehicles at charging points which are run by different operators – similar to the way third-party network operators are used in telecommunications. For example, eRoaming offers EV users cross-operator billing processes, whether through a smartphone app, by card, or potentially through vehicle-based identification. Interoperable platforms like these make barrier-free electric mobility possible, with EV users able to easily charge and pay at any charging station anywhere in Europe.

Similarly, in 2017, the Open Fast Charge Alliance was founded to create, through roaming, a premium network of fast chargers all over Europe. The founding members of the Open Fast Charging Alliance include Fastned (the Netherlands), Sodetrel (France), Smatrics (Austria), Grønn Kontakt (Norway), and GOtthard FASTcharge (Switzerland). Together, the alliance members own and operate more than 500 fast chargers in six markets. They provide 24/7 customer service and ensure maximum network uptime. The alliance is also open to other networks adhering to these standards. The alliance aims to focus on bilateral roaming agreements between these high-quality networks by implementing open standards like the Open Charge Point Interface (OCPI). The first of these implementations are planned for within the year.

56 *Daimler AG, BMW Group, Daimler AG, Ford Motor Company and the Volkswagen Group with Audi and Porsche form Joint Venture: IONITY – Pan-European High-Power Charging Network Enables E-Mobility for Long Distance Travel, 2017, retrieved from http://media.daimler.com/marsMediaSite/en/instance/ko/BMW-Group-Daimler-AG-Ford-Motor-Company-and-the-Volkswagen-Group-with-Audi-and-Porsche-form-Joint-Venture-IONITY--Pan-European-High-Power-Charging-Network-Enables-E-Mobility-for-Long-Distance-Travel.xhtml?oid=30112770*

In Mainland China, the Government has issued a standard called “Charging and Battery Swap Service Information Exchange for Electric Vehicles” (T/CEC 102.1-2016) to construct architecture that exchanges information between EV charging infrastructure points and unites the charging interface protocol. The standard can facilitate interconnection across different charging service platforms and realise data exchanges between EV charging infrastructure networks. In Beijing, a public charging facility platform has been built to provide an open interconnection platform for service providers to connect their charging network to this open platform or even their individual chargers to the platform. This public service management platform uses IoT and big data analytics technology to support the construction of charging facilities in Beijing and to support the exchange of information between participating stakeholders.

3.4 Views and recommendations

Recommendation 5: Create connections between stakeholders
In recent years, various activities have been held which include seminars, meetings and various dialogue sessions, in which representatives of industry stakeholders have been keen to participate in order to communicate with one another. For example, APAS organised some events like the APAS R&D Centre Showcase and technology sharing seminars; and established communication platforms like EVSIG, which involved stakeholders from the local EV industry. Between 2018 and 2019, EPD held 9 seminars or workshops to promote the installation of EV charging facilities.[57]

The overwhelming success of these activities shows that stakeholders in the local EV charging industry in Hong Kong are willing to collaborate and cooperate with each other. It is now time for these stakeholders to work together to develop strategies and a roadmap to encourage the further adoption of EVs and the expansion of the EV charging network in Hong Kong. Key stakeholders include the Government, the two power companies, charging service providers, property management offices, universities, R&D institutes and EV user groups.

This collaboration of stakeholders can also facilitate the sharing of frontline opinions and data. These important sets of data – the number and status of people using home chargers, for example – can allow the policy makers and the industry to leverage big data analytics and open data strategies to facilitate long-term planning of the distribution and density of the EV charging infrastructure in Hong Kong.

A reference model for a possible platform is the Hong Kong Connected Vehicles Cluster (HKCVC), formed by the HKPC, which brings over 30 enterprises together from the automotive and accessories industry, mobile networks, and the transportation and infrastructure industries to stimulate knowledge exchange and business development among practitioners in the connected vehicles industry to tap into new business opportunities in this promising sector.

Recommendation 6: Encourage private sector’s participation and promote paid charging services
Similar to the HKSAR Government, most overseas governments have prioritised home charging as the most suitable and the most preferred daily charging method for general EV users. The second option is EV chargers at workplaces or semi-public locations. The third option is the use of public EV chargers for those without home chargers or for the purposes of opportunity charging. These government development strategies follow the above principles. However, the policy makers alone cannot make this prioritisation strategy succeed. The private sector must also contribute to the development of both private and public EV charging facilities.

57 *Environmental Protection Department, News and Events, retrieved from https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/promotion_ev.html*

The adoption of paid charging services is critical as it opens up business opportunities that can attract more companies to the market. The “user pays” principle can facilitate the recovery of operating costs (i.e. the electricity tariff) and maintenance costs, and encourage EV users to put eco-driving principals into practice, which will help spread the burden of providing EV charging services and help sustainably cater for growing demand.

Recommendation 7: Support the development of innovative charging technologies

EVs and EV charging technologies are advancing and evolving at a very fast pace. Given the speed of change, the industry may hesitate to invest in research and development or adopt new technologies without clearly seeing the benefits of these investments. One consideration might be selecting dedicated demonstration sites which centralise the trial and demonstration of new EV charging technologies. This would facilitate more experience sharing and knowledge exchange among academic circles, and research and other industry sectors and aid the development of technology. These demonstration sites might also host exhibitions on emerging technologies, allowing these technologies to gain greater public acceptance when they are adopted in the community.

Kowloon East is one of the candidate sites for possible trials and demonstrations of new EV charging technologies. In the Government’s 2015 Policy Address, the Chief Executive announced that Kowloon East would be used as a pilot site to explore the feasibility of developing a smart city. For years, the Energising Kowloon East Office (EKEO) has been encouraging academic and research institutes to use Kowloon East as a test bed for developing innovative smart city solutions. The EKEO has also stipulated conditions for the area like requiring the provision of EV charging facilities for new land sale sites in Kowloon East, as well as ensuring the supply of real-time parking vacancy information at commercial car parks around the district.

CHAPTER 4: EMERGING TECHNOLOGY

4.1 Wireless charging

Charging a car without a wire works in a similar way to a wireless phone charger, but just on a larger scale. A wireless EV charger transfers electricity to the EV from a magnetic coil in the charger through an air gap to a second magnetic coil fitted to the EV. All that a driver has to do is park in the right place so that the coils are aligned, and charging will begin.

4.1.1 Wireless charging technology

The concept of wirelessly transferring electrical energy is not a new one. In fact, Nikola Tesla proposed a “world system” for “the transmission of electrical energy without wires” which used capacitive coupling in 1904 – 115 years ago. Since then, various wireless charging methods have been applied, like inductive coupling, magnetic resonance coupling, microwave and laser radiation, and others. Induction chargers use an induction coil to create an alternating electromagnetic field from a charging base, while a second induction coil in a portable device draws power from the electromagnetic field and converts it back into an electric current to charge a battery. Two induction coils in close proximity combine to form an electrical transformer. Greater distances between the sender and receiver coils can be achieved when the inductive charging system uses magnetic resonant coupling[58], which involves two copper coils being tuned to resonate at the same natural frequency – like two wine glasses which vibrate when a specific note is sung. The coils are placed a few feet apart. One coil is connected to an electric current, which generates a magnetic field that causes the second coil to resonate.

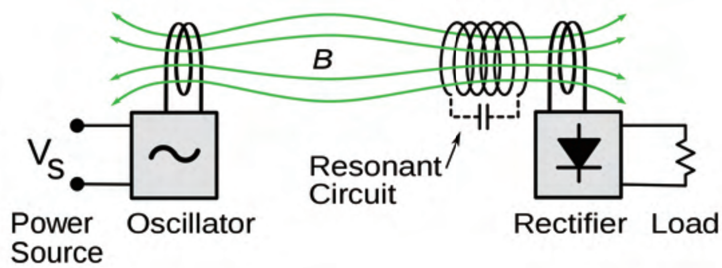

Figure 4-1 Diagram of the basic concept of resonant inductive coupling in a wireless power transfer system[59]

This magnetic resonance results in the invisible transfer of electric energy through the air from the first coil to the receiving coil. Just as major power plants generate alternating currents by rotating coils of wire between magnets, electricity moving through wires creates an oscillating magnetic field. This field also causes the electrons in a nearby coil of wires to oscillate, thereby transferring power wirelessly.

58 *EDN, Wireless charging: The state of disunion, 2019, retrieved from https://www.edn.com/wireless-charging-the-state-of-disunion/*
59 *Wikipedia, Resonant inductive coupling, 2018, retrieved from https://en.wikipedia.org/wiki/Resonant_inductive_coupling*

The transfer efficiency is further enhanced if both coils are tuned to the same magnetic resonance frequency and are positioned at the correct angle to make wireless charging possible, as this creates high efficiency over large gaps. Magnetic resonance coupling occurs when both the power sources and receiving devices are specially-designed magnetic resonators with approximately the same natural frequencies, with operating frequencies in a MHz band. Magnetic resonance coupling is capable of wirelessly transferring between three and seven kilowatts of electric power to a vehicle parked in a garage or on the street.

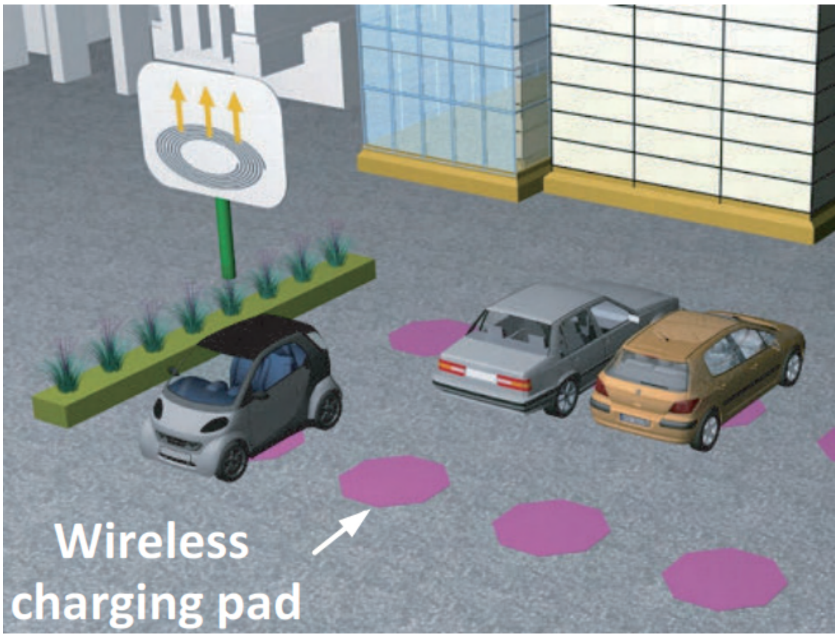

Figure 4-2 Stationary wireless charging[60]

4.1.2 Benefits and business opportunities

Wireless charging offers the ultimate convenience for consumers and enables safe charging in potentially hazardous environments where electrical sparks could cause an explosion. It also permits charging where grease, dust or corrosion would prevent clean electrical contact. Wireless charging also creates durability, as it does not wear out electrical contacts with multiple insertions of plugs.

The global wireless EV charging market is projected to grow at a compound annual growth rate (CAGR) of 49.38% from 2020 to 2025, and reach a market size of USD7,094.8 million by 2025. This market growth will primarily be driven by such factors as an increase in demand for EVs due to government policies, subsidies favouring Electric Vehicle Charging Stations (EVCS), and technological advancements. The growing number of fast EV chargers will be another key driver for the wireless EV charging market.[61]

The emerging concept of dynamic charging involves charging coils installed under a road, which can continuously charge EVs when waiting at a traffic light or even while driving.

60 *ASME, Wireless charging of a supercapacitor model vehicle using magnetic resonance coupling, 2013, retrieved from http://umji.sjtu.edu.cn/lab/dsc/files/Papers/Conferences/2013_Fu_ASME.pdf*

61 *PRNewswire, Global Wireless EV Charging (Aftermarket/Retrofit and OE Market) Market 2017-2025 - Market is Projected to Grow at a CAGR of 49.38%, 2017, retrieved from https://www.prnewswire.com/news-releases/global-wireless-ev-charging--aftermarketretrofit-and-oe-market-market-2017-2025---market-is-projected-to-grow-at-a-cagr-of-4938-300529162.html*

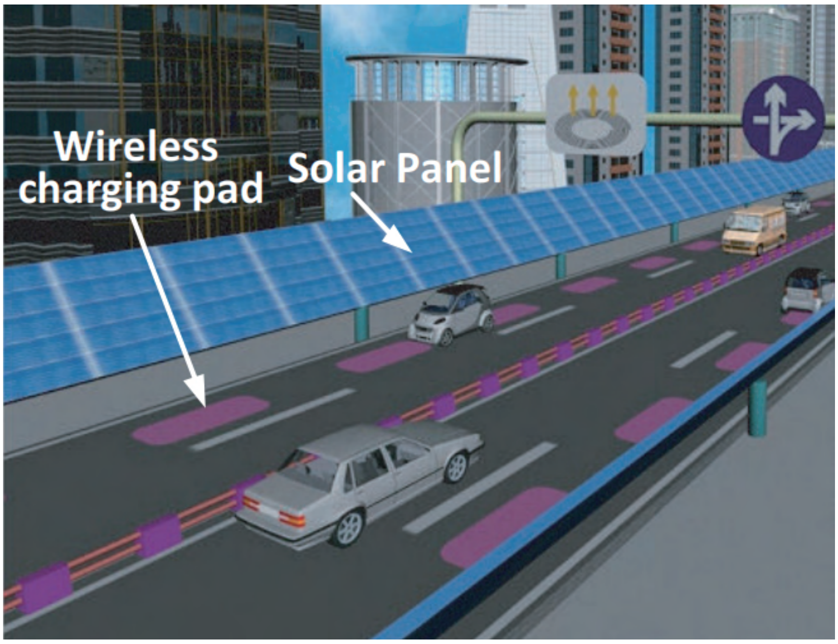

Figure 4-3 Illustration of dynamic charging[62]

4.1.3 Technological and standard developments

4.1.3.1 Technological developments by APAS and HKPC and worldwide auto manufacturers

APAS & HKPC

APAS & HKPC developed a wireless charging system in 2017 which uses magnetic resonance coupling technology and is compliant with the SAE standard. The system has 7kW of charging output power, which can fully charge a small-sized EV within three hours.

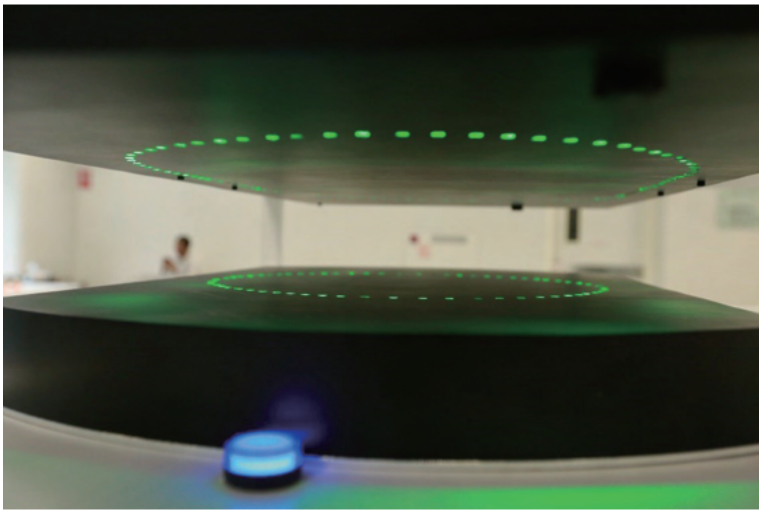

Figure 4-4 The wireless charging system developed by APAS&HKPC

62 ASME, Wireless charging of a supercapacitor model vehicle using magnetic resonance coupling, 2013, retrieved from http://umji.sjtu.edu.cn/lab/dsc/files/Papers/Conferences/2013_Fu_ASME.pdf

Plugless Power

"Plugless Power" is the name for a family of EVSE products manufactured by Evatran in the US that enable inductive charging of EVs. The Plugless Power EVSE wirelessly delivers electrical power to an on-board EV battery charger using electromagnetic induction which requires no physical connection to the vehicle. An EV equipped with a Plugless vehicle adapter can be charged by parking it over an inductive Plugless parking pad. The system is comprised of a control panel mounted on wall, a parking pad mounted on the floor and a vehicle adapter installed underneath the vehicle. It has 7.2kW continuous charging output power and an automatic alignment assist feature. Plugless Power has delivered EVSE for the Chevy Volt, the Nissan Leaf, the BMW i3 and the Tesla Model S.

Figure 4-5 The Plugless EV Charging System[63]

WiTricity

WiTricity is an American engineering company that manufactures wireless energy transfer devices which use resonant energy transfer based on oscillating magnetic fields. The WiTricity system has scalable charging rates of between 3.6 and 11 kW, and meets the needs of vehicles ranging from PHEVs with small capacity battery packs to EVs with high capacity and long-range battery packs.

Figure 4-6 The WiTricity EV Charging System[64]

63 *Plugless, 2nd generation plugless technical specifications, 2018, retrieved from https://www.pluglesspower.com/gen2-tech-specs/*

64 *WiTricity, DRIVE: Electric Vehicles, 2018, retrieved from http://witricity.com/products/automotive/*

Qualcomm Halo™

Qualcomm Technologies, Inc. (QTI) is an official founding and technology partner of the FIA Formula E Championship. The Qualcomm Halo™ Wireless Electric Vehicle Charging (WEVC) System uses resonant magnetic induction to transfer energy wirelessly, from a ground-based pad to a pad integrated with the vehicle. The system involves quick charging with high-power WEVC, supporting wireless power transfers at 3.7kW, 7.4kW, 11kW and 22kW with a single primary base pad and a wireless power transfer efficiency of 90%+.

Figure 4-7 The Qualcomm Halo™ Wireless Electric Vehicle Charging System[65]

Zonecharge

In 2016, Zonecharge in Mainland China developed a wired and wireless EV charging system based on resonant inductive coupling technology. Zonecharge provides a solution with charging rates of 3.7kW, 7.7kW, 22kW and 30kW[66].

Figure 4-8 Zonecharge wired and wireless electric vehicle charging system[67]

4.1.3.2 Standards

The SAE Recommended Practice J2954 has established an industry-wide specification that defines acceptable criteria for interoperability, electromagnetic compatibility, EMF, minimum performance, safety and testing for wireless charging of light duty electric and plug-in electric vehicles. Standardisation enables drivers to park their vehicles in spaces equipped with TIR J2954 equipment, and they need to take no further action to initiate a charge. The specification defines various charging levels based on the levels defined for SAE J1772 conductive AC charge levels 1, 2, and 3 (with some variations). Plans are in place to standardise this Recommended Practice after 2018 when receiving vehicle data. The contents of this Recommended Practice, including frequency, parameters, specifications, procedures and others, are to be re-evaluated in due course to allow for additional developments and future innovations.

65 *Qualcomm, The future of electric vehicle charging is wireless, 2018, retrieved from https://www.qualcomm.com/solutions/automotive/wevc*

66 *Zonecharge, 中惠創智電動車雙模 (有線 + 無線) 充電系統, 2018, retrieved from http://www.zonecharge.com/index.php?m=list&a=index&id=3*

67 *Qualcomm, The future of electric vehicle charging is wireless, 2018, retrieved from https://www.qualcomm.com/solutions/automotive/wevc*

The SAE Recommended Practice J2954 is meant to be used for interoperability, performance and emissions testing, where a single standard coil set has been chosen for the WPT Power Class 1 and 2 to 7.7kW, per Z-Classes (1 through 3), which is circular topology. However, there are two reference options for WPT 3 to 11kW per Z-classes (1 through 3) with two topologies. The next revision of the Recommended Practice will have one standard coil set for WPT 3. This SAE J2954 test station will provide a baseline where compatibility with the content of the Recommended Practices is demonstrated. Any future standards will use the performance-based J2954 standard testing station to establish a uniform way of demonstrating design for both the electrified vehicle (VA) and WEVSE (GA) components' safety, interoperability, performance and EM emissions through testing. The goal is to have a common methodology to validate wireless power transfer and alignment, production designs between different power classes, and topologies for both the vehicles and the associated infrastructure.[68]

4.1.4 Future development

4.1.4.1 Commercialisation

The newest "next best thing" that EV innovators are working on is Dynamic Electric Vehicle Charging (DEVC), which allows an EV to charge wirelessly as it is driving along a road. One of the most active players in stationary and dynamic charging is the wireless technology company Qualcomm, which recently developed and tested one of the world's first DEVC test tracks.

The feasibility study system is capable of charging an EV dynamically at up to 20 kW at highway speeds (100 km/h). Qualcomm also demonstrated simultaneous charging, in which two vehicles on the same track can charge dynamically at the same time. The vehicles are able to charge in both directions along the track, and even in reverse.[69] Qualcomm is now in discussions with infrastructure stakeholders, power companies, city planners, traffic planners, car park owners and other ecosystem stakeholders regarding the implementation of DEVC. However, any roll out of equipment is still some time away.

4.1.4.2 Fast wireless EV charging

Fast wireless EV charging is expected to deliver charging power of over 50kW. The growth of this type of charging is being driven by huge incentives from governments for the installation of fast chargers and public charging infrastructure subsidies. The increasing demand for commercial EVs is also contributing to the growth of high-power charging supply, since electric buses and electric trucks require a heavy power supply of more than 50kW to charge their high-capacity batteries.

4.2 Smart power distribution technologies for EVs

4.2.1 Power distribution technology

Effective power distribution can charge more EVs without the need for major infrastructure upgrades. Instead of installing additional physical electrical capacity, power distribution system can dynamically share existing power across more EV chargers in order to charge more EVs.

The aim of an effective power distribution system is to dynamically control the power of EV chargers according to the electricity loading of the building and thus to maximise the power utilisation of the building. The system can individually regulate the power supply of each charger according to its power demand, so as to harness potential unused capacity and in turn to facilitate the use of more chargers.

68 *SAE, Wireless Power Transfer for Light-Duty Plug-In/Electric Vehicles and Alignment Methodology J2954_201711, 2017, retrieved from https://www.sae.org/standards/content/j2954_201711/*

69 *Charged, Dynamic wireless charging: What's feasible? Q&A with Qualcomm's Graeme Davison, 2017, retrieved from https://chargedevs.com/features/dynamic-wireless-charging-whats-feasible-qa-with-qualcomms-graeme-davison/*

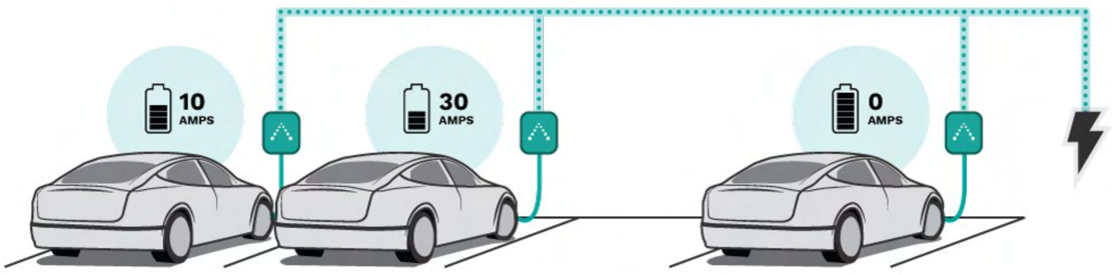

Figure 4-9 The dynamic EV charging power control concept[70]

Usually, the number of EV chargers is limited by the electricity capacity of the building. Even though power companies are able to supply extra power transformers, space limitations often prevent the installation of more EV chargers. The dynamic charging power system analyses the historical and real-time electricity loading data of residential, public and other car park zones, as well as the load profile trend, to forecast the maximum power available for EV charging. The system can adjust the loading of each charger effectively and continuously according to the demand.

4.2.2 Battery integrated charging solutions

EV charging stations which integrate renewable energy and second-life batteries is an emerging technology which can support the deployment of high power EV chargers. Renewable Energy (RE) sources can provide green energy, while also supporting the export of power to the grid when the generation of RE exceeds demand. Second life batteries are integrated into these systems to serve as an energy buffer and provide emergency energy upon potential loss of the grid connection.[71]

4.2.3 Benefits and business opportunities

The growth in the number of EVs may have a significant impact on the peak demand of the electricity distribution network of a city. Generally, most EV charging takes place in the evenings. Uncoordinated charging of a large number of EVs could result in excessive demand spikes that occur for just a few hours a day, while demand in the remaining parts of the day remains unaffected. This situation could have far-reaching consequences for all the stakeholders involved. There may be grid congestion due to power peaks and voltage drops. There may also be an increase in electricity costs due to the expenses involved in the generation of extra power and grid reinforcement. Such drawbacks can be overcome when EV charging is well managed so as to make better use of the available power generation and grid capacity.[72] This is already occurring in some developed countries, like Britain for example: at least 30 per cent of Britain's low voltage networks are likely to be upgraded in order to charge EVs by 2050, an expected investment of approximately £2.2bn (~€2.4bn at current exchange rates). On the other hand, smart power distribution charging could reduce, delay or even obviate the need to upgrade or replace these low voltage networks.[73] The large scale deployment of smart power distribution is essential to supporting the adoption of solar PVs, EV chargers and smart buildings; all of which are vital components of the development of a smart city.

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70 *EVE Australia Pty Ltd., Strata & Body Corporate Managed EV Charging Made Easy, 2016, retrieved from https://www.evse.com.au/apartment-ev-charging/*

71 *Ahmad Hamidi, Luke Weber, del Nasiri, EV charging station integrating renewable energy and second-life battery, 2013, retrieved from https://ieeexplore.ieee.org/document/6749937*

72 *Eurelectric, Smart charging: Steering the charge, driving the change, 2015, retrieved from https://www3.eurelectric.org/media/171787/sanchez-duran.pdf*

73 *Electric Nation, Research shows that smart charging can be key solution to challenge of network demand from EVs, 2017, retrieved from http://www.electricnation.org.uk/2017/09/05/research-shows-that-smart-charging-can-be-key-solution-to-challenge-of-network-demand-from-evs/*

4.2.4 Technological development

4.2.4.1 Charge point power distribution system

APAS & HKPC

APAS & HKPC has developed a semi-quick EV charging station called "Charging Pro" with the following features:

- An Intelligent Load Management System which is capable of regulating the power output of individual EV charging facilities to avoid overloading. This solution allows for more charging facilities in parking lots and can maximise power utilisation.
- A Charging Facility Monitoring and Management System, which can monitor and manage each networked EV charging facility to optimise operational efforts and the costs of running an EV charging service.

Figure 4-10 APAS& HKPC developed a semi-quick EV charging station called "Charging Pro"[74]

EVBox

EVBox is a leading global manufacturer of EV charging stations and charging management software. Their charging stations are capable of optimising existing charging infrastructure by creating and distributing the available power in an efficient and flexible manner. EVBox station features include load balancing, hub and satellite functions and "peak shaving". To explain these in more detail, operating charging stations requires that the source of power, for example an office building, carries the cumulative sum of the total capacity of all charging stations. The concept of load balancing means that the available capacity of the power source is distributed proportionally over all active charging stations – thus ensuring that optimal charging is provided to all EVs, subject to the capacity limits of the power source. A hub and satellite configuration allows multiple charging stations to operate cost effectively by connecting up to 20 charging points (or satellites) to each other through a single modem (the hub) and a "BackOffice" plan. Peak shaving helps prevent power consumption from exceeding the maximum capacity available when multiple EVs are charging simultaneously. The system will automatically reduce the power consumption of a charging session, or even pause sessions altogether, until sufficient power becomes available.[75]

74 *HKPC, Development of Low-cost Charging Equipment to Support Full Deployment of EV Charging Infrastructure in Hong Kong, 2017, retrieved from https://www.hkpc.org/en/industry-support-services/success-stories/5350-development-of-low-cost-charging-equipment-to-support-full-deployment-of-ev-charging-infrastructure-in-hong-kong?template=hkpc_text*

75 *EVBox, Smart charging technology - how does it work?, 2017, retrieved from https://www.evbox.com/learn/faq/how-does-smart-charging-work*

4.2.4.2 Building power distribution systems

The role of the low voltage power distribution system of any building is to network electrical power at one or more supply points and deliver it to individual electrical devices. The importance of the power distribution system to a building's operation makes these systems critical, meaning it is of paramount importance to have the best system and the best protection for that system. Additionally, in order to contribute power to a smart grid, power and distribution panels with additional features are required, since more complex communication and tele-control equipment is needed. Most buildings in Hong Kong are not equipped with EV charging stations, as the set-up costs of charging stations and the costs of upgrading the building's power distribution system are too high for most property management companies.

4.3 Vehicle-to-Home (V2H) and Vehicle-to-Grid (V2G) technologies

V2H and V2G technologies can provide a controllable, bi-directional electrical energy flow between a vehicle and the electrical grid. The electrical energy flows from the grid to the vehicle in order to charge the vehicle's battery.

4.3.1 V2H and V2G technologies

V2H is a system which supplies power to a home through the energy stored in an EV, while V2G is a system which allows for the sale of energy stored in an EV to the power grid and allows for recharging from power grid.

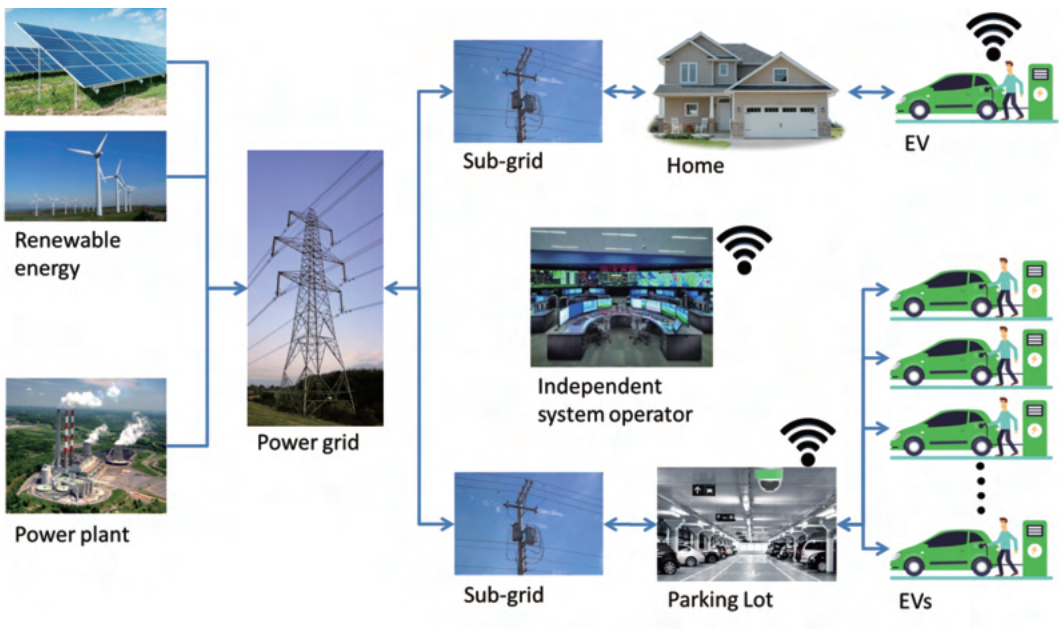

Figure 4-11 The V2G concept illustrated[76]

The primary physical elements of V2H and V2G systems are EVs equipped with battery-management software and hardware that allows a two-way flow of electricity; and communications technologies which mediate between vehicles and grid operators. In a standard connection between an electricity grid and a vehicle, power flows from the grid to the vehicle and charges the vehicle's battery. The implementation of V2G requires communications technologies and algorithms which sense grid status, determines whether vehicles should be providing or drawing electricity from the grid at any given time, ascertain the status and availability of vehicles that can provide the services needed, and track the services provided by vehicles so that owners can be paid for making their vehicles available.[77]

76 *National Renewable Energy Laboratory, Critical Elements of Vehicle-to-Grid (V2G) Economics, 2017, retrieved from https://www.nrel.gov/docs/fy17osti/69017.pdf*

77 *National Renewable Energy Laboratory, Critical Elements of Vehicle-to-Grid (V2G) Economics, 2017, retrieved from https://www.nrel.gov/docs/fy17osti/69017.pdf*

4.3.2 Benefits and business opportunities

In addition to being a device for travel, EVs can also act as very large energy storage devices. In terms of V2H systems, a user can charge their EV through solar energy during the day or charge it from the power grid during off-peak hours with a lower electricity tariff, and then supply power to their homes from the EV during night time or peak hours. The EV can also work as an emergency backup power supply for the home during blackouts or brown outs.

For V2G system, if most of the EVs in the city charge during off-peak hours, the energy stored in EVs can be used as a power source for the power grid during peak hours. Such an arrangement can mitigate peak power consumption and the variations between peak hours and off-peak hours.

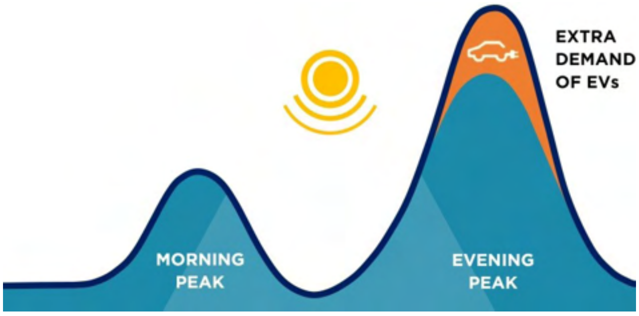

Figure 4-12 Power consumption (blue line) variations within a day without a V2G system[78]

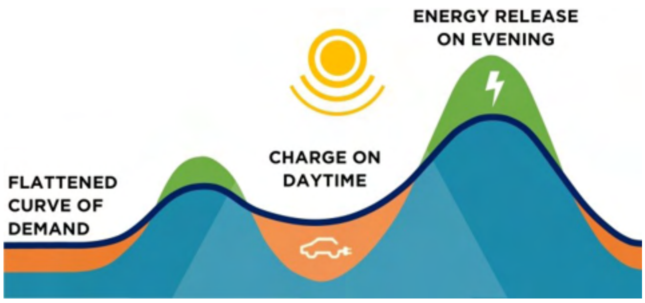

Figure 4-13 Power consumption (blue line) variations within a day with a V2G system[79]

V2G systems could provide enormous capacity for renewable energy storage and help stabilise the power grid power supply.

4.3.3 Technological and standard developments

Below are some examples of successful V2H and V2G projects that have launched or will be launching in different markets.

4.3.3.1 Japan

Japan currently is a leader in the EV industry and has already set up a V2H standard called the Electric Vehicle Power Supply System Association (EVPOSSA) in order to encourage foreign companies to follow suit. Nissan, Honda and Toyota are also conducting research into and development of V2H technologies, with Nissan having already created a practical application for the technology.

In May 2016, Nissan and Enel, a multinational power company based in the UK, announced a collaborative V2G trial project in the UK. Nissan and Enel will install and connect 100 V2G units for Nissan LEAF and e-NV200 owners. The project claims that EV owners will be able to sell stored energy from their vehicles back to the grid at a profit.

78 *Amsterdam Vehicle 2 Grid, The solution to sustainable urban mobility and energy, 2014, retrieved from http://www.amsterdamvehicle2grid.nl/*
79 *Amsterdam Vehicle 2 Grid, The solution to sustainable urban mobility and energy, 2014, retrieved from http://www.amsterdamvehicle2grid.nl/*

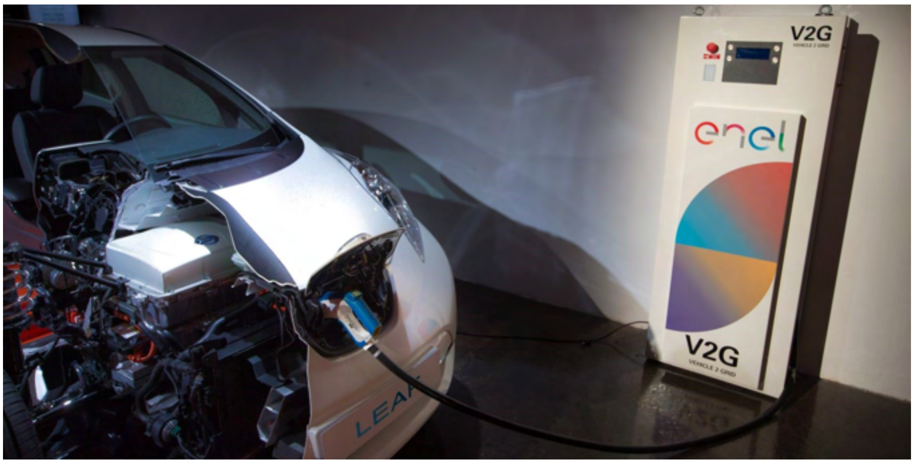

Figure 4-14 Nissan is launching a new vehicle-to-grid project with Enel in the UK[80]

Furthermore, Nissan has hinted that they plan to release a new Leaf model in the US that will include V2G functionality, in addition to self-driving capabilities. Nissan made this announcement during the 2017 Consumer Electronics Show in Las Vegas.

Figure 4-15 Nissan has released a V2G-ready vehicle[81]

4.3.3.2 Denmark

Denmark currently is a world leader in wind power generation. In 2015, Denmark derived 42 per cent of its energy from wind power. Beginning in 2009, Denmark has launched a number of V2G-related projects.

One example is the EDISON project, which ran from 2009 to 2013. This was a partially state-funded research project on the island of Bornholm in eastern Denmark to lay the groundwork for a series of turbines that will be built by 2025. These will provide 50 per cent of the island's total power, while V2G systems will provide backup to prevent negative impacts to the grid. The EDISON project saw Danish and international companies develop optimal system solutions for EV system integration, including network issues, market solutions and optimal interactions between different energy technologies. The Danish electric power system provides an optimal platform for demonstration of such developed solutions.

80 *Electrek, Nissan to launch a new vehicle-to-grid project with Enel in the UK, 2016, retrieved from https://electrek.co/2016/05/11/nissan-vehicle-to-grid-enel-uk/*

81 *V2city-expertgroup, Nissan, to release Vehicle to Grid-ready vehicle, 2017, retrieved from http://v2city-expertgroup.eu/2017/02/02/nissan-to-release-vehicle-to-grid-ready-vehicle/*

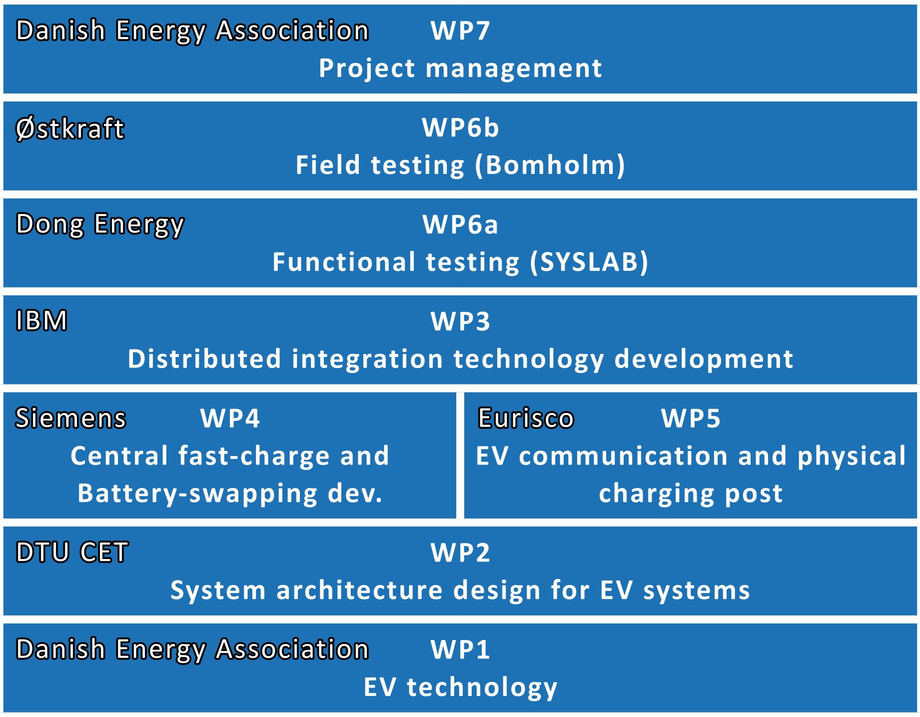

Figure 4-16 The structure of the EDISON project[82]

Following the EDISON project, the Nikola project commenced in 2013. This was a Danish research and demonstration project which focuses on synergies between an EV and a power system in a laboratory setting at the Risø Campus (DTU). DTU is a partner in the project along with NUVVE and Nissan. The Nikola project was completed in 2016.

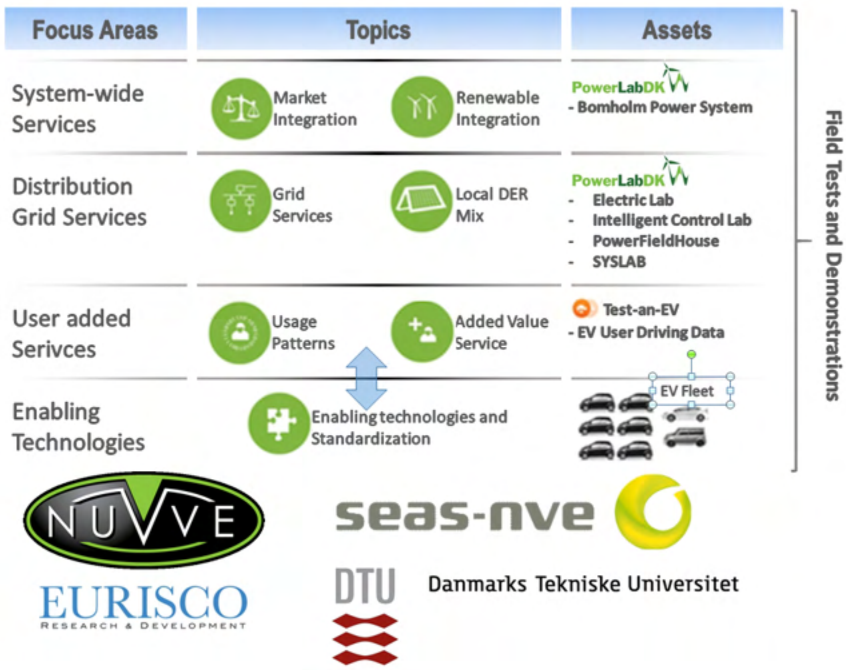

Figure 4-17 Nikola project overview[83]

82 *EETimes, IBM joins Danish EDISON Project to develop smart grid for electric vehicles, 2009, retrieved from https://www.eetimes.com/ibm-joins-danish-edison-project-to-develop-smart-grid-for-electric-vehicles/*

83 *Nikola, Welcome to the Nikola project, 2016, retrieved from http://www.nikola.droppages.com/*

The most recent Danish project - Parker project, which started in August 2016 and ran for two years. This project sought to prove that series-produced EVs, as part of an operational fleet, can support the Danish power system through providing power and energy services. The organisations DTU, NUVVE and INSERO cooperated with a large car OEM, Nissan, and a Danish fleet owner, Frederiksberg Forsyning, for this pilot project. The project was novel in a number of ways:

- The use of series-produced vehicles and charging spots to demonstrate advanced smart grid services, including V2G.
- The project aims of reconciling real-world user needs and requirements through vehicles supporting the power system.
- Validating that these vehicles can be vertically integrated into the power system, i.e. supporting network operation from the distribution grid to the market.[84]

4.3.3.3 Amsterdam

"Resourcefully", an environmental consultancy in Amsterdam launched the "Amsterdam Vehicle 2 Grid" project in March 2013. The system came about through the interconnection of several elements: solar energy, E-mobility, a smarter electricity grid for Amsterdam, and households with information management systems.

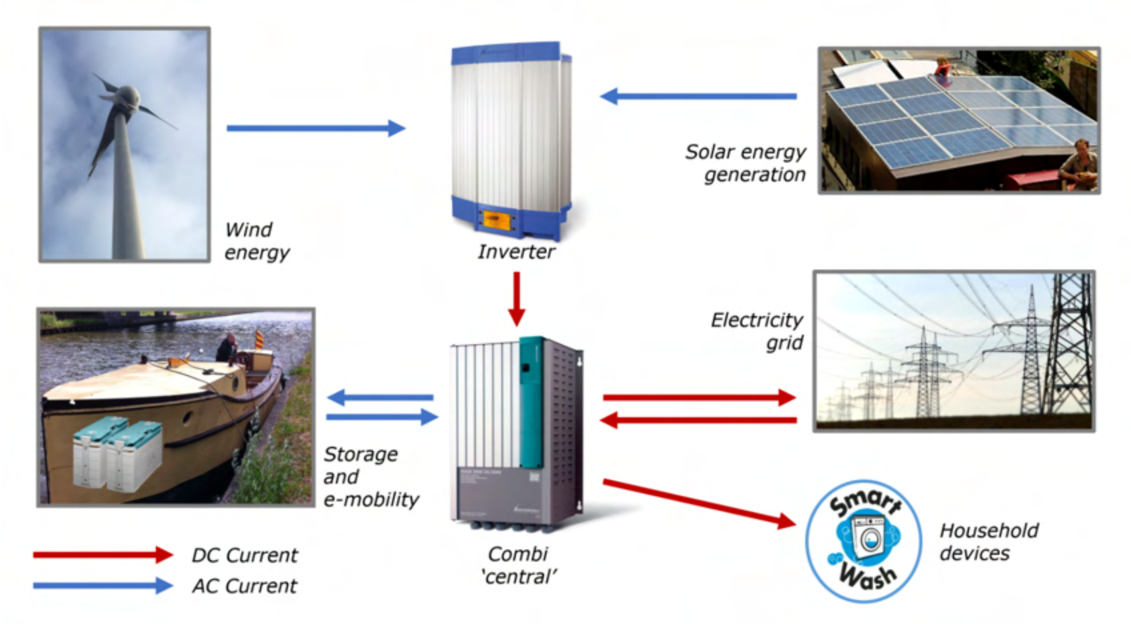

Figure 4-18 Operation of the "Amsterdam Vehicle 2 Grid" system[85]

After two years of running, Resourcefully claimed that their Amsterdam V2G project had had the following results:

- The households involved in the project increased their energy independence or had zero emission energy autonomy (rising from 34 per cent to 65 per cent with V2G);
- A significant decline in energy exchanges with the electricity network – 45 per cent less the situation without V2G;
- Storage size efficiency reached 93 per cent with a 10 kWh storage capacity. This is close to the maximum storage level, and more storage capacity contributes little extra;
- Operational energy losses through storage in DC batteries and re-conversion when consuming the energy was about 80 per cent;
- Degradation of the batteries' capacity after two years was quite limited, only about six or seven per cent.[86]

84 *Energiforskning, Parker, 2016, retrieved from https://energiforskning.dk/en/node/8432*
85 *Amsterdam V2G, System Info, 2015, retrieved form http://www.amsterdamvehicle2grid.nl/de-installatie/*
86 *Amsterdam V2G, General Results, 2015, retrieved from http://www.amsterdamvehicle2grid.nl/graphs/*

4.3.3.4 The US

SolarCity is a subsidiary of Tesla, Inc. that specialises in solar energy services in the US. In October 2016, they launched two projects: the Powerwall 2 storage system and a solar roof. The solar roof aims to generate sustainable energy from the rooftops of houses. The Powerwall 2 storage system will take energy generated by any source – whether a solar roof, another solar power system, or even the grid – and use it when it is most beneficial, such as during night time, during a power outage, or when the customer can make money from doing so.[87] Tesla's Powerwall costs USD6,200 and can store 14 kilowatt-hours of energy. For reference, the average electricity consumption of a residential customer in 2015 was 901 kWh per month.

Figure 4-19 Tesla's Powerwall 2[88]

4.3.3.5 Vehicle-to-Home systems in Hong Kong

APAS has developed and completed a V2H project based on Japan's EVPOSSA V2H standard called the Smart V2H System. This project involved the development of a complete system capable of transferring vehicle power to a home, from a grid to a vehicle, from a solar power source to a home and other combinations.

The Smart V2H System consist of three major components:
Electric Vehicle Power System (EVPS)
Home Battery Power Storage System
Solar Power System

Figure 4-20 Smart V2H System developed by APAS

87 *Tesla, Tesla and SolarCity, 2016, retrieved from https://www.tesla.com/en_HK/blog/tesla-and-solarcity?redirect=no*
88 *Business Insider, Tesla is sending hundreds of Powerwall batteries to Puerto Rico — here's how the rechargeable battery works, 2017, retrieved from http://www.businessinsider.com/how-teslas-powerwall-2-works-solar-roof-2017-5/#which-is-then-sent-to-a-homes-electrical-panel-to-provide-power-6*

The Electric Vehicle Power System (EVPS) controls the power flow in the Smart V2H System by implementing the EVPOSSA V2H/V2L protocol. A DC/DC converter in the EVPS is used to transfer power from the home battery to the EV battery and vice versa. Meanwhile, a DC/AC inverter in the EVPS is used to deliver power from the home battery or the EV battery to household appliances. The Home Battery Power Storage System gathers power from a renewable energy generation unit (i.e. the Solar Power System) or the EV and supplies power to the household during emergencies or in on-demand situations. The Solar Power System includes solar panels and a DC/DC converter which provides renewal power to the home battery. The DC/DC converter includes a Maximum Power Point Tracking (MPPT) function, which can maximise the power extraction from the solar power system. With the Smart V2H System, APAS has established fundamental V2L/V2H technology and implemented the mature EVPOSSA protocol. In future, APAS plans to migrate from V2L/V2H to Smart Grid V2G technology and expand into other V2H/V2G standards as needed in future.

4.3.3.6 Standard

The ISO 15118 standard for road vehicles-V2G communication interfaces is an international standard defining a V2G communication interface for bi-directional EV charging and discharging. ISO 15118 consists of the following sections, each of which is detailed in a separate standard document: [89]

- ISO 15118-1: General information and use-case definition
- ISO 15118-2: Network and application protocol requirements
- ISO 15118-3: Physical and data link layer requirements
- ISO 15118-4: Network and application protocol conformance test
- ISO/FDIS 15118-5: Physical and data link layer conformance test
- ISO/DIS 15118-6: General information and use-case definition for wireless communication
- ISO/CD 15118-7: Network and application protocol requirements for wireless communication
- ISO/FDIS 15118-8: Physical layer and data link layer requirements for wireless communication

4.3.4 Future development

4.3.4.1 Integrate with smart electricity grids

A smart grid is an electricity network that incorporates a suite of information technology, communications technologies, and other advanced technologies to monitor and manage the transport of electricity from a number of generation sources to meet the varying electricity demands of end users.

Smart grids allow for better coordination of the needs and capabilities of all generators, grid operators, end users, and electricity market stakeholders, as they operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability, resilience and stability.[90] Energy storage mechanisms that are used as either a local electricity source or a grid resource will play a key role in the future. The storage of renewable energy and the subsequent dispatch of that energy on an as-needed basis will be an important key to the future of energy storage and its interaction with the utility grid. Batteries are capable of responding to requests for changes in output very quickly. EVs, given their projected penetration into the market, have the potential to provide, via their batteries, the most important component in the evolution of the smart grid: energy storage.[91]

89 *ISO, 43.120 - Electric road vehicles, 2018, retrieved from https://www.iso.org/ics/43.120/x/*

90 *Tugrul U. Daim, Xiaowen Wang, Kelly Cowan and Tom Shott, Technology roadmap for smart electric vehicle-to-grid (V2G) of residential chargers, 2016, retrieved from https://innovation-entrepreneurship.springeropen.com/articles/10.1186/s13731-016-0043-y*

91 *Richard A. Raustad, The Role of V2G in the Smart Grid of the Future, 2015, retrieved from https://www.electrochem.org/dl/interface/spr/spr15/spr15_p53_60.pdf*

4.3.4.2 Integrate with retired EV batteries

Vehicle batteries are known to lose capacity with time and cycling. Prior research has commonly assumed that EV batteries will be fit for purpose – i.e. powering EVs – down to a remaining energy storage capacity of between 70 and 80 per cent. When an EV battery reaches this remaining storage capacity level, it is generally assumed that the battery should be retired, as they will no longer meet the range and mobility needs of EV drivers. After being retired from their EVs, these former vehicle batteries can have a “second life” where they serve as stationary energy storage devices for the electricity grid.

Nissan took part in a project on second life battery storage and V2G systems with Enel and Eaton as partners. Together, the companies equipped Nissan’s regional office in France with 100 V2G bi-directional chargers (using the CHAdeMO standard) supplied by Enel, with an energy storage system combining 64 “second life” LEAF EV batteries installed by Eaton combined with a solar energy generation system. With one MWh of energy stored in the system, and an additional one or two MWh stored in EVs connected to the system and parked in the building’s parking lot, the system provided a decent level of energy storage for the building.[92] The project illustrated how integrating a V2G system with retired EV batteries could provide more stable energy storage capacity for the grid and at the same time extend the life cycle of vehicle batteries, creating less overall environmental impact.

4.4 Connected Vehicles (CVs)

As technology advances, the Internet has become an essential and evolving part of everyone’s daily lives. Now, it is not only computers and smart phones that are connected to the Internet, but household appliances, smart devices and vehicles. A new term has recently surfaced: the “Connected Vehicle”, or CV. Connected Vehicles are sometimes referred to as the “Internet of Vehicles”, or IoV, as well.

CVs involve an integration of three networks: an inter-vehicle network, an intra-vehicle network and a vehicular-based mobile Internet. With three networks integrated into one, CVs are essentially large-scale distributed systems for wireless communications and V2X information exchanges; where “X” can be vehicles, roads, people and networks. These V2X exchanges take place according to agreed communication protocols and data interaction standards, with examples including the IEEE 802.11p WAVE standard and, potentially, cellular technologies. CVs can create an integrated network for supporting intelligent traffic management, intelligent dynamic information services and intelligent vehicle control, representing a typical application of Internet of Things (IoT) technology in an intelligent transportation system (ITS).[93]

What kinds of technologies are involved in a typical CV? Basically, CVs are equipped with Internet access via Wi-Fi or cellular network such as GSM, HSDPA, LTE telecommunications technologies or the 5G networks that are expected to be deployed and supported by 2020.[94] Other short-range communications technologies are also employed. Once the vehicle is connected to the Internet, it can communicate with a back-end cloud system to access a number of different services, such as automated emergency calls, navigation services, real-time traffic messages and many others.

At the core of the CV is the vehicular Global ID (GID) terminal. This is the vehicle’s communication gateway which operates from an integrated or mounted terminal which has global, ubiquitous network connectivity. It is also an intelligent in-vehicle sensor with global positioning and global online identification (essentially an “online license plate”) functionality. The GID integrates the vehicle's smart information sensor, networking, and online license plate.

92 *InsideEVs, Largest “Second Life” Battery Storage and V2G Project Ever To Power Nissan Office, 2016, retrieved from https://insideevs.com/largest-second-life-battery-storage-and-v2g-project-ever-to-power-nissan-office/*
93 *APEC, White Paper of Internet of Vehicles (IoV), 2014, retrieved from http://mddb.apec.org/Documents/2014/TEL/TEL50-PLEN/14_tel50_plen_020.pdf*
94 *Telefonica, Infographic: Connected cars by 5G, 2017, retrieved from https://iot.telefonica.com/blog/infographic-connected-cars-by-5g*

Figure 4-21 A connected car is equipped with several wireless transceivers like Wi-Fi, Bluetooth and LTE transceivers.[95]

4.4.1 Overseas connected vehicle services case studies

4.4.1.1 eCall

The eCall system is a European initiative which provides an automated message to emergency services following a traffic accident or a crash which includes the precise location of the accident. An “in-vehicle eCall” is an emergency call (an E112 wireless call) generated either manually by the vehicle occupants by pushing a button, or automatically via the activation of in-vehicle sensors after a crash. When activated, the in-vehicle eCall device will establish an emergency call which carries both voice and data directly to the nearest emergency services. The voice call enables vehicle occupants to communicate with a trained eCall operator. At the same time, a basic data set will be sent to the eCall operator taking the voice call. This data set contains information about the incident including the time, the precise location, basic vehicle identification, the eCall status (indicating whether the eCall was manually initiated or automatically triggered), and information about a possible emergency service provider.

In Europe, eCall devices must be fitted into all new models of cars and light vans as of 31 March 2018. Similarly, EU member states were required to put in place the necessary Public Safety Answering Points (PSAP) infrastructure to process eCalls by 1 October 2017.

Some researchers estimate that eCalls will be able to reduce emergency response times by 40 per cent in urban areas and by 50 per cent in rural areas.[96]

95 *Laird, Connecting and Protecting the Connected Car, 2016, retrieved from https://www.lairdtech.com/news/laird-completes-novero-acquisition*
96 *Transport Research Library, UK, "Commission takes first step towards rollout of eCall system", 2011*

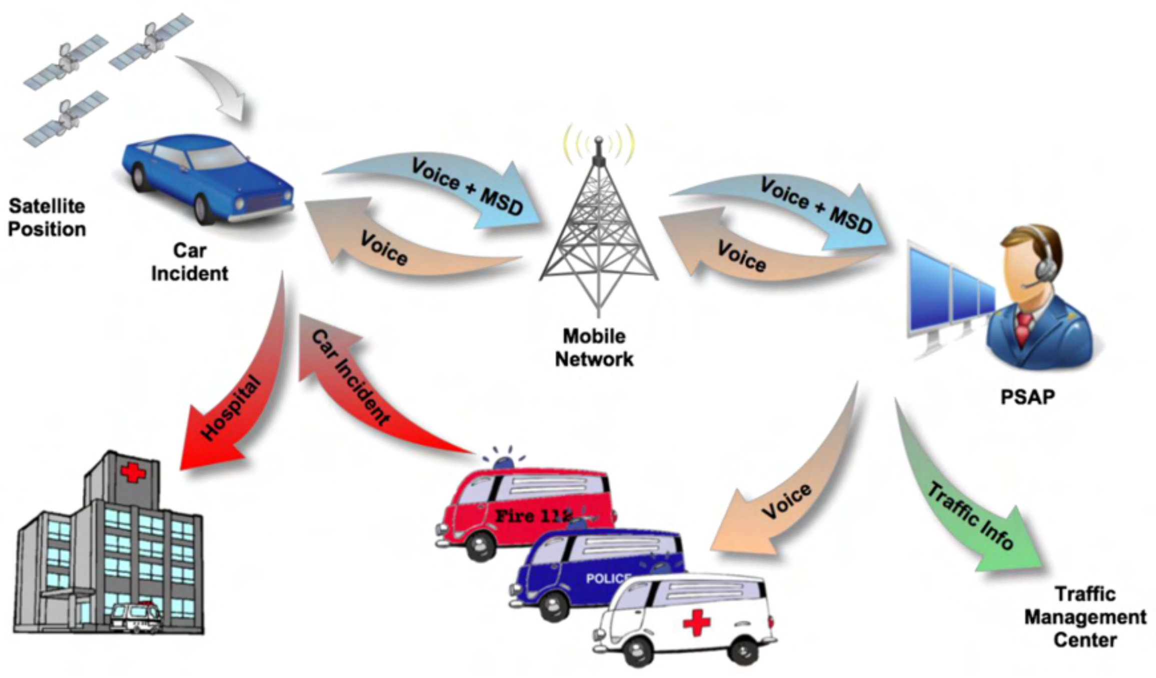

Figure 4-22 The eCall service chain[97]

Previously, the I_HeERO project, which ran from January 2015 to December 2017, aimed to prepare the PSAP infrastructure for the introduction of pan-European eCalls. Other aims of the project were to boost member state investment in PSAP infrastructure and the interoperability of the service, prepare member states for the deployment of Hazardous Goods Vehicle eCalls, including those carrying dangerous goods; eCalls for long distance buses and coaches and eCalls for Powered Two Wheeled machines (PTWs). The project also performed PSAP Conformity Assessments and studied advancements in the management of data and next generation 112 calls.

The I_HeERO project was operated by 11 EU member states: Bulgaria, Cyprus, Czech Republic, Finland, Germany, Greece, Ireland, Italy, Luxembourg, Portugal and Slovenia, and included about 100 commercial partners and associated partners. Luxembourg successfully completed the eCall conformity assessment in August 2017, becoming the first EU member state to declare themselves ready to implement eCalls.

4.4.1.2 OnStar

OnStar is a subsidiary of General Motors that provides a variety of in-vehicle services, all of which are delivered via a Code Division Multiple Access (CDMA) cellular connection. OnStar is also the name of a set of services that are available in new GM family vehicles. The services include:

- Emergency services – Automatic crash response, emergency services, weather conditions, Crisis Assist and roadside assistance;
- Security – Stolen vehicle assistance, remote ignition block, stolen vehicle slowdown and theft alarm notification;
- Navigation – the car's screen-based navigation system allows occupants to discover value in the places they travel to;
- Connections – OnStar 4G LTE and Wi-Fi hotspot, hands-free calling, third party apps and services;
- Vehicle Manager – Diagnostics reports, OnStar Smart Driver, Remote Access and Location Manager Functions.

97 *HeERO2, Implementation roadmap and guidelines for eCall deployment in Europe, 2015, retrieved from http://cordis.europa.eu/docs/projects/cnect/5/325075/080/deliverables/001-HeERO2D65eCallGuidelinesv11ICOORAres2222865.pdf*

All of these features can be accessed by pressing a blue "OnStar" button, a red "emergency services" button, or a hands-free calling button. Each OnStar system is capable of gathering data from both the On-Board Diagnostics (OBD-II) system and built-in Global Positioning System (GPS) functionality. These functions use CDMA cellular technology for voice communications and data transmissions. The OnStar call centre will also be notified when the OBD-II system determines that the vehicle's airbags have deployed.

General Motors established OnStar in 1995, and the first OnStar units were made available in several Cadillac models for the 1997 model year. OnStar is primarily available in GM vehicles, though a licensing agreement also made OnStar available in several other models between 2002 and 2005. A stand-alone unit was also released in 2012, which provides access to some OnStar services. OnStar has provided services throughout the US, Canada, Mainland China, Mexico, Europe, Brazil, and Argentina.

Figure 4-23 OnStar's three button interface provides access to hands-free calling, operator-assisted navigation and emergency services[98]

4.4.1.3 Mainland China

BAIC EV, a leading brand in Mainland China's EV industry, released their model EU260 EV in 2016. This model was equipped with the "i-link Intelligent and Connected System", the first Chinese system to apply 4G technology to the interactions between telematics and a cloud platform.[99] The i-link is the first system in Mainland China equipped with voice identification technology, an information recreational system and a unified ultra-large information board in the cabin. The system is also equipped with digitalised green driving information systems and wireless charging equipment for mobile phones, and allows drivers to access services like remote inquiries, examination, control and early warning systems. BAIC EV has also made a major breakthrough in revolutionising telematics, which is normally limited to primary integration with the Internet, by triggering interactions among various sensing technologies and Internet resources to provide smart solutions to problems for vehicle users.[100]

At the same time, other automakers in Mainland China are cooperating with different Internet and technology enterprises to further develop CV technologies.[101]

98 *Lifewire, GM's OnStar Service: How Does It Work?, 2017, retrieved from https://www.lifewire.com/gms-onstar-service-534811*
99 *BAIC Group, 浦東車展 | 北汽集團打出靚麗品牌名片, 2016, retrieved from http://www.baicgroup.com.cn/news_detail.php?type=7&id=1711*
100 *Telematics News, BAIC shows i-Link connectivity and plans US R&D, 2016, retrieved from http://telematicsnews.info/2016/01/13/baic-shows-i-link-connectivity-and-plans-us-rd_ja7133/*
101 *Oriental Daily, 內地車聯網商機萬六億, 2017, retrieved from http://orientaldaily.on.cc/cnt/finance/20171004/00202_012.html*

Automaker	IT enterprise	Projects
GAC GROUP	Tencent	Intelligent driving, artificial intelligence, big data and after-sales services
SAIC Motor	Alibaba	Applying Alibaba's AliOS to different SAIC vehicle models
SAIC Motor	JD.com	Developing renewable energy and autonomous electric trucks
Dongfeng Motor Group	JD.com	Developing renewable energy and autonomous electric trucks

4.4.1.4 Hong Kong

In the Smart City Blueprint Consultancy Study Report published by the Innovation and Technology Bureau in June 2017, the Hong Kong Government came up with the following smart mobility strategies and initiatives which are related to CVs:

- Develop and install "In-Vehicle Units" (IVUs) which allow motorists to receive real-time traffic information and pay tunnel fees remotely through the IVUs, without having to use toll booths;
- Complete the installation of about 1,200 traffic detectors on all strategic roads to provide real-time traffic information by 2020;
- Engage the public in the development of a detailed Electronic Road Pricing (ERP) Pilot Scheme and implementation strategy in Central and adjacent areas and in 2019;
- Introduce a pilot of intelligent traffic signal systems with sensors for pedestrians and vehicles at road junctions starting from 2021;
- Adopt an automatic toll system without toll booths for the new Tseung Kwan O-Lam Tin Tunnel which incorporates the findings of field trials, subject to the approval of the Legislative Council on the necessary legislative amendments, by 2021;
- Facilitate trials of autonomous vehicles in the West Kowloon Cultural District and other areas as appropriate;
- Facilitate public transport operators' plans to introduce new electronic payment systems for public transport fare collection, which paying attention to the systems' reliability, user friendliness and efficiency;
- Encourage public transport operators to open up their operational and vehicle data to other stakeholders;
- Pilot the use of technology to deter the improper use of loading and unloading bays and illegal parking from 2018;
- Explore the use of a crowd management system at Kai Tak Sports Park which will facilitate the monitoring of people and vehicle flows during major events;
- Release real-time information on franchised buses through mobile devices by 2018 and information display panels at government Public Transport Interchanges and 1,300 covered bus stops by 2020;
- Install new on-street parking meters which will provide real-time parking vacancy information and support multiple payment systems, including remote payments through mobile applications, starting from 2019 or 2020.
- Encourage the owners and operators of existing public car parks to provide real-time parking vacancy information using technology solutions which will help drivers find parking spaces; and examine practicable measures which will require new public car parks to provide real-time parking vacancy information.[102]

102 *Innovation and Technology Bureau, Hong Kong Smart City Blueprint, 2017, retrieved from https://www.smartcity.gov.hk/*

4.4.2 Benefits and business opportunities

4.4.2.1 Charging management and parking reservations

The Internet of Things is now an important and growing part of the parking industry. Apps that guide you to a parking space give information on the status of car parks, while parking management systems notify parking enforcement staff about violators.

In terms of CVs, optimal parking lot recommendations can be made based on driver behaviours and subjective demands. Candidate parking lots can be screened, based on users' subjective parking demands (e.g. they are looking for a parking lot with an EV charging station), and processed through multiple attribute decision making. This means that the most suitable parking lots can be recommended to drivers, who can then immediately book a parking spot at the chosen lot online.

4.4.2.2 Fleet management for commercial EVs

Fleet management is defined as the management of commercial vehicles. Aspects of fleet management include vehicle financing, vehicle maintenance, vehicle telematics (Internet-based tracking and diagnostics), driver management, speed management, fuel management and health and safety management. In the CV environment, real-time information on tracking, diagnostics and fuel management can be uploaded to a cloud server at the fleet management centre for processing, which will improve logistics efficiency, productivity, and allow for predictive fleet maintenance.

The fleet database can be set up to notify fleet managers on matters such as annual vehicle examinations, traffic violations and tickets and renewal of insurance. Additionally, a driving profile can be set up for drivers, including such categories as average speed, frequency of detours, duration and frequency of breaks, rigorousness of manoeuvres and even gear shift positions. Metrics on all these parameters can be recorded to measure and improve performance. Over-The-Air (OTA) security and control of fleet vehicles is also possible, which can disable vehicles remotely. In case of accidents, the vehicle damage status, accident location and data on any pre-accident manoeuvres can help the company answer questions about accident responsibility and insurance liability.

4.4.2.3 Predictive maintenance

Predictive maintenance for commercial vehicles is usually taken care by fleet management. For private vehicles, CVs help drivers schedule and arrange predictive maintenance by connecting the vehicle to the maintenance service provider’s server. Real-time information on vehicle diagnostics will then be uploaded to the maintenance service provider, allowing them to order spare parts or any other items necessary to maintenance procedures.

4.4.2.4 Driving behaviour analysis

In a CV environment, big data technologies offer new solutions to improve traffic safety and efficiency by tracking and recording driving data which allows for analysis and evaluation of driving behaviour. Potential features and applications of the system will remind drivers to improve any poor driving behaviours, and perhaps refer them to personalized vehicle insurance policies or active safety applications.

4.4.2.5 Insurance

As discussed above, driving behaviour analysis data can offer CV drivers references to personalized vehicle insurance policies. These will create new opportunities for insurance companies, such as Usage-Based Insurance (UBI) and its two variants: “Pay As You Drive” (PAYD) and “Pay How You Drive” (PHYD). Usage-Based Insurance began as an effort to collect data to enhance insurance ratings and billing revenue. The concept of PAYD applies to the quantity of an individual’s driving – that is, the amount of the insurance charged is based on their actual usage of the vehicle. This pricing model is analogous to metered billing for electricity charges. PHYD on the other hand is based on the quality or style of an individual’s driving. This model takes into consideration a person's driving style and driving behaviour to determine whether a driver is aggressive or makes good decisions while driving. UBI provides an opportunity to enhance current practices by saving lives, making a positive impact on society, helping the economy, and protecting the environment. When an accident occurs, the vehicle damage status, driving record, location, and data on pre-accident manoeuvres can also help insurance companies identify the parties responsible for the accident.

4.4.2.6 Traffic control

Connected vehicle drivers can obtain the real-time traffic information, real-time images of traffic on main roads from the vehicle terminal, and can automatically recommend an optimized route to the driver to avoid traffic jams. Driving on a quick and seamless route can also reduce the chances of a traffic accident and improve road safety. Real-time information on the vehicle's location and speed can be uploaded to traffic management systems to help traffic information providers to broadcast accurate information.

4.4.2.7 Infotainment

CVs can also offer new infotainment options by delivering popular content to passengers. Today, vehicle entertainment is mostly confined to FM radio and Bluetooth connectivity. However, as high-speed networks come into mainstream use, popular high bandwidth streaming services may become available in connected vehicles. Passengers will then have much broader digital content choices. For example, Apple and Google are currently competing to becoming the "brains" behind in-car infotainment. Apple's CarPlay function embeds the familiar iOS experience into a vehicle's dashboard, which in turn gives access to a variety of third-party apps available in the Apple App Store. Android Auto can also stream music from Google Play Music straight into a connected vehicle. The system also allows a driver to access their preferred apps and content in the vehicle. Passengers can also purchase or rent media on the go.[103]

4.4.3 Future development

4.4.3.1 Enabling the development of technology

CVs are dependent on reliable and secure networks for their operation, but there are two main technical issues which need to be tackled: network speed and capacity and cyber security.

Beyond cost and security considerations, both in terms of data privacy and the potential for hacking, the speed of the network to which they are connected presents a bottleneck preventing CVs from reaching their full potential. Current 4G networks do not have the capacity or the speed to enable a truly connected experience or deliver safe and reliable services. The ultimate solution for CVs is a 5G network which has very low latency, faster, greater and higher band frequencies, more simultaneous connections and more reliability. With the latency of 5G being around ten times lower than LTE networks, and with throughput reaching up to ten gigabytes per second – compared with LTE's maximum of 300 megabytes – operators will be able to deliver significant improvements in the capacity and range of their networks.[104] Currently, many countries are working to find ways to upgrade their networks to 5G. Mainland China has provided commercial 5G services at the end of October 2019.[105] By 2025, it is predicted that 67 million automotive 5G vehicle subscriptions will be active.[106]

On the cyber security front, once vehicles are connected to the Internet, new opportunities for hackers can arise. A secure environment is absolutely necessary for IoV development and road safety. The security risks of IoV are centred on five aspects: CVs themselves, V2X communications, data security, intelligent devices, and service platforms; with the first three items mostly related to the vehicles.

103 *Forbes, How Will Consumers Benefit From Connected Cars?, 2016, retrieved from https://www.forbes.com/sites/janakirammsv/2016/06/06/how-will-consumers-benefit-from-connected-cars/#4f303dd24a05*
104 *GSMA, The Road to 5G and the Rise of Connected Cars, 2017, retrieved from https://www.gsma.com/iot/news/road-5g-rise-connected-cars/*
105 *www.gov.cn, 5G套餐來了, 2019, retrieved from http://www.gov.cn/xinwen/2019-10/31/content_5447177.htm#1*
106 *Telefonica, Infographic: Connected cars by 5G, 2017, retrieved from https://iot.telefonica.com/blog/infographic-connected-cars-by-5g*

CV cyber security elements include the Electronic Control Unit (ECU), the Controller Area Network (CAN) bus, the Telematics Box (T-Box), the on-board operating system, the on-board diagnostics (OBD) interface and the In-Vehicle Infotainment (IVI) system. Hackers may be able to attack the connected vehicle through an over-the-air firmware upgrade, through illegal data injection, illegal device access, "man-in-the-middle" attack, and other means. A secure CV should include numerous elements, like a secure bootloader, secure network communication, a partition, or firewall, between the vehicle control network and cloud-based apps, a secure firmware OTA update, theft protection, anomaly detection, intrusion detection, data encryption and data rollback in case of an update failure.

V2X communication cyber security elements include different types of wireless communication like Wi-Fi, Bluetooth, Zigbee, a cellular network, satellite communications, LTE V2X (Long-Term Evolution Vehiculale to X), Dedicated Short-Range Communication (DSRC) and others. With so many elements in play, fast-moving and dynamic changes in network topology make it difficult to detect cyber attacks. Secure V2X communication should include encryption and decryption, generation and verification of signatures, access controls, a guarantee that data will be transmitted securely without tampering, authentication verification, authorization and data integrity checks.

The problem of data security is very serious, as falsified or tampered traffic management data, or data related to automobile operations can threaten the safety of the vehicle and other traffic on the road. Automakers should formulate data classification standards, insist on higher-level management requirements for data privacy, and restrict open sharing of sensitive data.[107]

With the implementation of 5G networks and more trustworthy security protocols, CVs can reach their full potential and present incredible new opportunities for drivers and other transportation stakeholders, some of which are listed below.

Firstly, online vehicle telematics checks, annual inspections and monitoring will be able to remotely determine a vehicle's operational legality – answering questions like "Has the vehicle's license expired?" or "Does the vehicle have any illegal modifications?" – its regulatory compliance and the license status of the driver; all of which will reduce vehicle management costs, change industries and save lives.

Secondly, vehicles will have Internet-based online IDs. This will amount to an online presence on a quasi-real-name basis, which will make the operation of falsely registered, smuggled or illegally modified vehicles much more difficult. These IDs will also enable easy bundling with mobile payments and driver and passenger information records, thereby increasing overall security and credibility in both cyberspace and the physical world. Cyber license plates and black boxes alone have the potential to spawn entire industries.

Finally, a large number of smart terminals may well emerge that are tailored to CVs, both in-vehicle and handset-based. In the future, CV terminals should come with special human-to-machine interfaces which will be able to connect to in-vehicle screens and serve as mobile payment terminals. They should also feature CV location-based service and satellite navigation system functionality, as well as special CV cloud services such as an intelligent transportation system, automotive insurance, rescue, positioning and search, vehicle checking, remote diagnostics and networking with the GID. With these interface terminals in hand, the CV will become an integral part of the mobile world.[108]

107 *CAICT, Introduction of IOV Security, 2017, retrieved from https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/Events/2017/Oct2017CIIOT/CIIOT/9.Session4-1%20Introduction%20of%20IoV%20Security-%E7%94%B0%E6%85%A7%E8%93%89V3.pdf*

108 *Huawei, Internet of Vehicles: Your next connection, 2017, retrieved from http://www1.huawei.com/enapp/28/hw-110836.htm*

4.4.3.2 Data analytics

Data analytics will be an important component of the CV environment, and automakers will easily be able to collect enormous amounts of data through V2X. However, converting the collected data and creating benefits from it will requires the use of big data analytics. Such analytics will be able to flexibly filter out irrelevant metrics and obtain smart data, with models "knowing" what to store and what to ignore.

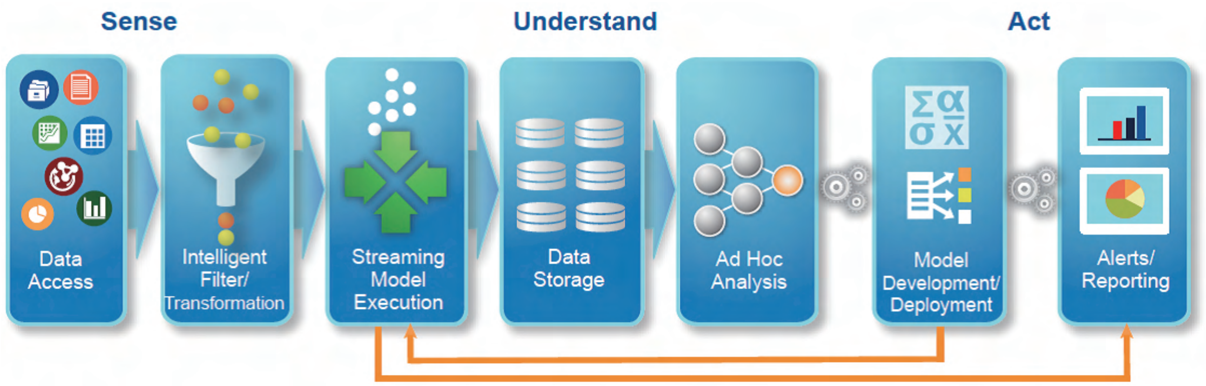

Figure 4-24 A full IoT analytics life cycle[109]

Big data analytics are often described in terms of the "Four Vs":

- Volume – The scale of data
- Variety – The diversity of data
- Velocity – The speed of data
- Veracity – The certainty of data

Big data encompasses enormous amounts of information collected from multiple internal and external sources such as location data, transactions, social media, enterprise content, sensors and mobile devices. Automakers can leverage this data to adapt their products and services to better meet customer needs, optimize operations and discover new sources of revenue.[110] Below are a few ways in which automakers can derive benefits from big data analytics:

- Accelerate the development of smart mobility: Use a continuous flow of vehicle and customer data to inform product managers and R&D teams and create timely, high-quality recommendations for advanced product planning;
- Improve customer loyalty and retention: Use predictive models, streaming data and a variety of customer information to help automakers uncover contextually relevant, persuasive messages for vehicle owners;
- Strengthen integrated vehicle health management programmes: Apply analytics to streaming vehicle data as a way to deliver more effective alerts and recommendations to improve vehicle quality, safety and longevity;
- Fine-tune service and repair opportunities: Use real-time knowledge of where vehicles are actually traveling to help dealer service departments provide timely customer repairs while optimizing their parts inventory.[111]

4.5 Autonomous driving

An autonomous vehicle can sense the environment and navigate automatically without receiving any human control inputs. Such vehicles use several different technologies to detect their surroundings and position, such as ultrasonic, computer vision, Radar, LIDAR, odometry and GPS.

109 *IotONE, SAS® Analytics For IoT, 2016, retrieved from https://www.iotone.com/guide/sas-reg-analytics-for-iot-apply-analytics-and-visualization-to-iot-data-at-the-source/g232*
110 *IBM, The FOUR Vs of Big Data, 2013, retrieved from http://www.ibmbigdatahub.com/sites/default/files/infographic_file/4-Vs-of-big-data.jpg*
111 *SAS®, Analytics for IoT: Connected Vehicles, 2016, retrieved from https://www.sas.com/content/dam/SAS/en_us/doc/productbrief/sas-analytics-for-iot-connected-vehicles-108518.pdf*

4.5.1 Technical overview of autonomous vehicles

4.5.1.1 SAE Standard definitions

SAE J3016™ levels and definitions are listed below:

Level 0 – No Automation: The full-time performance by the human driver governs all aspects of the vehicle's dynamic driving tasks, even when enhanced by warnings or intervention systems

Level 1 – Driver Assistance: The driving mode-specific execution by a driver assistance system of aspects of either steering or acceleration and deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving tasks.

Level 2 – Partial Automation: The driving mode-specific execution by one or more driver assistance systems of aspects of both steering and acceleration and deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving tasks.

Level 3 – Conditional Automation: The driving mode-specific performance by an Automated Driving System of all aspects of the dynamic driving tasks with the expectation that the human driver will respond appropriately to requests to intervene.

Level 4 – High Automation: The driving mode-specific performance by an Automated Driving System of all aspects of the dynamic driving tasks, even if the human driver does not respond appropriately to requests to intervene.

Level 5 – Full Automation: The full-time performance by an Automated Driving System of all aspects of the dynamic driving tasks under all roadway and environmental conditions that can be managed by a human driver.[112]

4.5.1.2 Sensory Technology

For fully automated driving to become the norm, driverless vehicles will need to exceed the capabilities of human drivers. Different types of sensors enable the vehicles to make sense of their environment in a more foresighted way than human beings are capable of.

a) Ultrasonic sensors

Figure 4-25 Ultrasonic sensor technology[113]

112 *SAE, SAE International Releases Updated Visual Chart for Its "Levels of Driving Automation" Standard for Self-Driving Vehicles, 2018, retrieved from https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles*

113 *The Drive, Here's How The Sensors in Autonomous Cars Work, 2017, retrieved from http://www.thedrive.com/tech/8657/heres-how-the-sensors-in-autonomous-cars-work*

Sensing range: 0 – 2m

Vehicles use ultrasonic sensors to detect obstacles in their immediate vicinity, be the cars, pedestrians, kerbs or bollards. These sensors play an important role in automated parking. However, ultrasonic sensors can only be used at very low speeds.

b) Computer vision

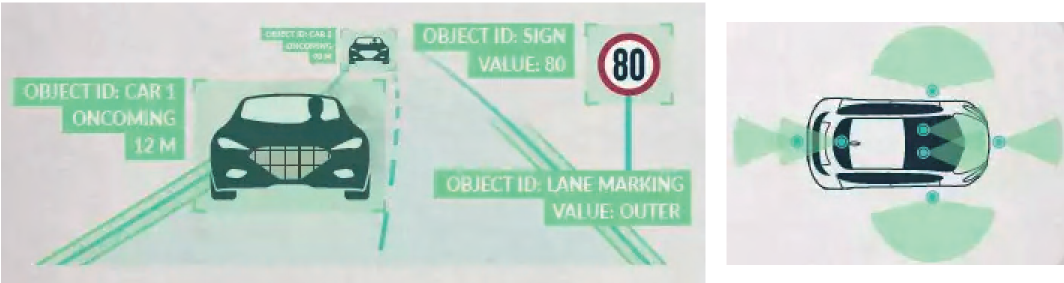

Figure 4-26 Computer vision technology[114]

Sensing range: 0 – 120m

Several cameras generate images of the vehicle's surroundings, imitating human eyesight. Stereo cameras are even capable of 3D vision, which allows the cameras to determine range. In contrast to other sensors, cameras can detect colours and fonts, and are therefore able to interpret traffic signs, traffic lights or lane markings. They can also act as a back-up system should other sensors fail which increases the vehicle's overall safety and system security. However, the visual range needs to be increased to 250 metres to enable more anticipatory driving. Weather limitations such as fog, rain or low sun currently increase the risk of failures and need to be overcome. Recognition algorithms also need to be improved as, for example, pedestrians are presently only recognised correctly in 95 per cent of cases.

c) Radar sensors

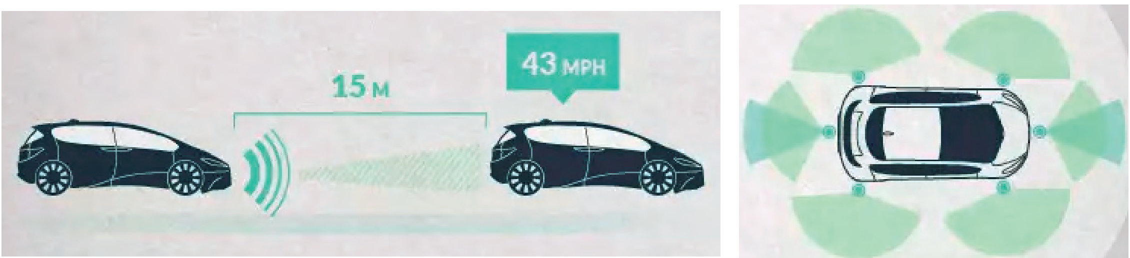

Figure 4-27 Radar sensor technology[115]

Sensing range: 0 – 250m

Radio Detection and Ranging (Radar) sensors send out electromagnetic waves. When they encounter an obstacle, the waves are reflected back to the sensor, revealing how far away an object is and how fast it is approaching. Short- and long-range radar sensors are deployed all around an autonomous vehicle. These are able to track the speed of other vehicles in real time. They also contribute to vehicle safety by increasing the redundancy of autonomous driving systems. However, 2D radar sensors are not able to determine an object's height as they only scan horizontally. This can cause problems, when driving under a bridge for instance. The 3D radar sensors currently in development will likely solve this issue.

114 *The Drive, Here's How The Sensors in Autonomous Cars Work, 2017, retrieved from http://www.thedrive.com/tech/8657/heres-how-the-sensors-in-autonomous-cars-work*

115 *The Drive, Here's How The Sensors in Autonomous Cars Work, 2017, retrieved from http://www.thedrive.com/tech/8657/heres-how-the-sensors-in-autonomous-cars-work*

d) LIDAR sensors

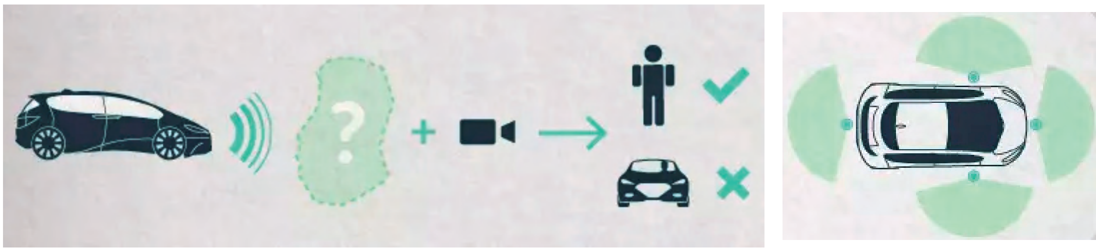

Figure 4-28 LIDAR sensor technology[116]

Sensing range: 0 – 200m

Light Detection and Ranging (LIDAR) sensors scan the environment with a non-visible laser beam. This low-intensity, non-harmful beam visualises objects and measures ranges, creating a 3D image of the car's environment. Combined with data from the onboard cameras, LIDAR sensors allow obstacles to be accurately identified – for instance whether there is a vehicle or a pedestrian in front of the car. Since rare earth metals are needed to produce LIDAR sensors, they are currently much more expensive than radar sensors. Also, innovative LIDAR sensors currently being tested use flashes instead of a constant beam. These will provide a significantly improved comprehensive view around the entire vehicle.

Figure 4-29 Sensors generate a three-dimensional map to aid navigation[117]

116 *The Drive, Here's How The Sensors in Autonomous Cars Work, 2017, retrieved from http://www.thedrive.com/tech/8657/heres-how-the-sensors-in-autonomous-cars-work*

117 *UCSUSA, Self-Driving Cars Explained, 2017, retrieved from http://www.ucsusa.org/clean-vehicles/how-self-driving-cars-work#.WhaJq1WWbDc*

e) Odometry

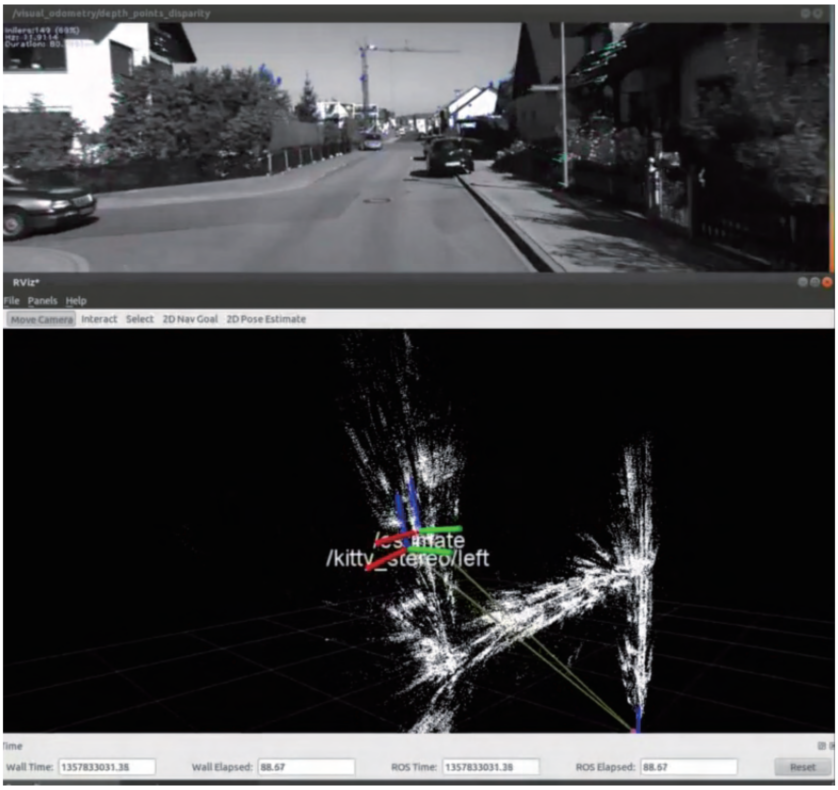

Figure 4-30 Visual odometry in an autonomous car[118]

In navigation, odometry is the use of data from the movement of actuators which estimates changes in position over time through devices such as rotary encoders that measure wheel rotations. In addition, odometry universally suffers from precision problems, since wheels tend to slip and slide over the ground, creating variations in distance when compared to wheel rotations. These errors are compounded when the vehicle operates on non-smooth surfaces. Odometry readings become increasingly unreliable over time as these errors accumulate and compound.

Visual odometry, on the other hand, is the process of determining equivalent odometry information using sequential camera images to estimate the distance travelled. Visual odometry allows for enhanced navigational accuracy in vehicles using any type of locomotion on any surface.

118 *Karol Hausman, Visual odometry for an autonomous car, 2013, retrieved from https://www.youtube.com/watch?v=NevS8byw16o*

f) GPS and Cloud Technology

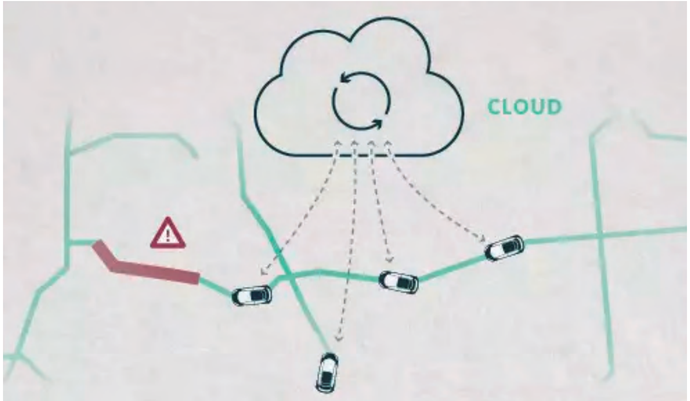

Figure 4-31 GPS and Cloud Technology[119]

GPS records the position of a vehicle and the cloud serves as a dynamic “electronic horizon” which offers a highly accurate real-time location of a vehicle in motion. Data is constantly updated by the collective intelligence of the vehicle, for instance reporting closed lanes or defective traffic lights, providing the vehicle with an image of its surroundings and allowing other vehicles to better anticipate what lies ahead. However, while prototypes are already using this dynamic electronic horizon, the vehicle’s location on a map is not yet precise enough on highways and in rural areas. Using “swarm intelligence” from multiple vehicles will only be possible only when a sizable amount of CVs are on the road.

4.5.1.3 Control Technology

Autonomous vehicles use a variety of techniques to detect their surroundings, and advanced control systems interpret vast amounts of sensory information to identify appropriate navigation paths, along with obstacles and relevant signage. Autonomous vehicles must have control systems that are capable of analysing sensory data to distinguish other cars on the road. While the design details vary, most self-driving systems create and maintain an internal map of their surroundings. Software then processes those inputs, plots a path and sends instructions to the vehicle’s “actuators”, which control acceleration, braking and steering. Hard-coded rules, obstacle avoidance algorithms, predictive modelling, and “smart” object discrimination – for example identifying the difference between a bicycle and a motorcycle – help the control system follow traffic rules and navigate obstacles. Partially autonomous vehicles may require a human driver to intervene if the system encounters uncertainty; while fully autonomous vehicles may not even have a steering wheel. Self-driving cars can be further distinguished as being “connected” or not, indicating whether they can communicate with other vehicles and/or traffic infrastructure, such as next generation traffic lights. However, most prototypes do not currently have these capabilities.[120]

4.5.1.4 Telematics Technology

Telematics is an amalgamation of the words “telecommunications” and “informatics”. Telematics, in a broad sense, is any use of telecommunications which is integrated with information and communications technology. It is the technology involved in sending, receiving and storing information relating to remote objects – like vehicles – via telecommunication devices.[121] Telematics includes anything from GPS systems to navigation systems. For human drivers, insurers are able to use telematics to record driving behaviour and predict the risk of an accident. Telematics systems are also capable of determining which autonomous safety features are active at any time.

119 *The Drive, Here's How The Sensors in Autonomous Cars Work, 2017, retrieved from http://www.thedrive.com/tech/8657/heres-how-the-sensors-in-autonomous-cars-work*
120 *UCSUSA, Self-Driving Cars Explained, 2017, retrieved from http://www.ucsusa.org/clean-vehicles/how-self-driving-cars-work#.WhaJq1WWbDc*
121 *Fleetmatics, What is Telematics?, 2016, retrieved from https://www.fleetmatics.com/what-is-telematics*

Telematics technologies in autonomous vehicle include cellular networks such as LTE or 5G networks, and Global Navigation Satellite Systems (GNSS) likes GPS, GLONASS, Galileo or BeiDou systems. As described previously in the "GPS and cloud" sub-section, when an autonomous vehicle uses highly accurate real-time location data from GNSS systems and real-time traffic information from the cloud, the vehicle will be able to quickly and accurately find the best route to the destination.

4.5.1.5 Why autonomous driving for EVs?

A question people often ask is why autonomous driving and EVs must be combined. Must self-driving cars be electric? The short answer is "no" – or, more accurately, "not yet". It is possible to create a competent self-driving car which uses an older internal combustion engine as the power source. However, there are six compelling reasons that explain why it is most likely that self-driving cars will be overwhelmingly electric – that is, six reasons why the two technologies are destined to merge:[122]

1) Technology-focused early adopters want both innovations in the same vehicle
Automotive innovations are expensive, and they generally are seen in premium cars first. The types of early adopters that can afford such price premiums often identify "technological differentiation" as their incentive, which means they want automakers to include both electric and self-driving features in the same car, as in the new Mercedes-Benz S Class. As these innovations eventually trickle down and become more affordable, the initial pairing demanded by early adopters usually carries through to the mass market as well.

2) It is easier to implement autonomous features on EVs
Between the multitude of sensors required and their advanced on-board computing hardware and software, self-driving cars require more power from a vehicle's electrical subsystem. Today, ICE engines still largely use 12V electrical systems, running off a single lead-acid battery. The higher voltages and energy stored in an EV battery pack allow much more design freedom when it comes to implementing self-driving hardware and software. It is also simpler to control an electric motor and battery pack than an internal combustion engine, with its thousands of moving parts and complex cabling ("drive by wire" technology, for example, is a more natural fit for EVs). Indeed, in their prototyping of autonomous vehicle features, General Motors, Nissan and Google have each opted to use EVs as a starting platform.

3) Wireless charging integrates seamlessly with autonomy
A self-driving car will have a very hard time refilling its tank with gasoline. The process would either require the driver, or a gas station attendant, or a robot to do it. Wireless charging, which is now coming to the market for some plug-ins from Audi, Toyota and other brands, eliminates this problem. An autonomous vehicle can drive itself to an available parking spot, align itself properly and self-charge using wireless charging. Moreover, it can move itself away from the charging pad when charging has been completed, allowing for a higher utilisation rate of the charging infrastructure, whereas EVs that are not self-driving would be stuck in position until their owners moved them. Wireless charging is also more efficient when vehicles are properly aligned – and self-driving cars will be able to park themselves optimally every time, thus ensuring the highest possible wireless charging efficiency. Finally, autonomous vehicles enable "opportunistic charging": rather than waiting until a battery pack is nearly drained, a vehicle can charge itself when it is between driving tasks.

122 *Lux Research, Six Reasons Why Electric Vehicles and Autonomous Vehicles Will Inevitably Merge, 2016, retrieved from http://blog.luxresearchinc.com/blog/2016/09/six-reasons-why-electric-vehicles-and-autonomous-vehicles-will-inevitably-merge/*

4) More efficient self-driving extends range, which is an EV pain point
All developers of EVs continue to struggle with "range anxiety", and any technologies that can extend driving range are warmly welcomed in the field. Early studies indicate that self-driving technology may improve driving efficiency by five to ten per cent, thanks to smoother braking and acceleration, as well as more logical coasting and regenerative braking brought about by advanced mapping and predictive algorithms. For EVs, extending driving range by five to ten per cent using autonomous driving will be an extended benefit. More tests are needed to quantify the exact size of this bump, but the promise is there. Once realised, automakers could use capitalise on it by either designing EVs to drive longer distances (lower range anxiety for same price), or reduce the price of EVs (same range anxiety, but a smaller battery pack and therefore a lower price).

5) Both technologies will mature in the same time frame
EVs are still not widely popular and fully self-driving cars are still a distant promise, however, both technologies are progressing steadily. Year by year, battery technology gets less expensive which helps EVs sell better. Year by year, sensors and software improve, allowing driver assistant features to become more sophisticated and make steady progress towards full autonomy. It is estimated that around 2030 both technologies will be mature – that is, when plug-ins will become the mainstream drivetrain type, and when full autonomous driving will be achieved. If this time frame and predictions of synchronicity are accurate, then the two technologies will enter into a virtuous cycle, with each benefitting the other.

6) Both technologies will become mandated by governments
As EVs become more affordable and more mainstream, and as climate change and environmental concerns rise, the idea that governments will continue to allow automakers to sell ICE-powered cars that are priced competitively seems unlikely. Indeed, a number of governments around the world are already debating on when to ban the sale of ICE-powered cars entirely. A couple of countries have already set a timeline to stop production and sales of ICE-powered vehicles entirely. Similarly, once driver assistant features can be conclusively proved to be significantly safer than human drivers, governments will likely mandate this feature as standard equipment, just as happened did with airbags, anti-lock brakes, electronic stability control, and other innovations. It is foreseeable that most governments around the world will force automakers to implement both technologies in the future and finally ban the sale of ICE-powered vehicles altogether.

4.5.2 Case studies from other markets

4.5.2.1 The US

In terms of autonomous vehicle development, Google started working on autonomous vehicles in 2009. In 2016, they extended the project as a separate company called Waymo, which then became Alphabet's self-driving unit. In July 2019, Waymo was given permission by California regulators to transport passengers in its vehicles.[123] Working with Waymo has not been Intel's only foray into autonomous driving – the company is also working with Ford on autonomous R&D vehicles.

123 *California Public Utilities Commission, Autonomous Vehicle Pilot Permits Issued, retrieved from https://www.cpuc.ca.gov/avcissued/*

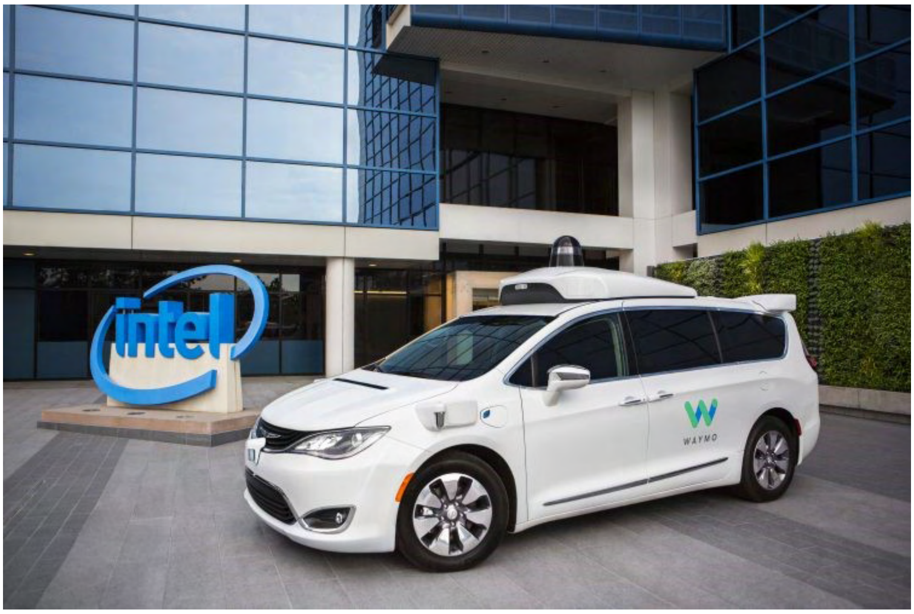

Figure 4-32 A Waymo self-driving car[124]

In 2016 in the US, Uber began testing prototypes of autonomous vehicles made by Volvo and has struck a deal to buy up to 24,000 self-driving cars from Volvo over the course of three years, beginning in 2019.[125] In June 2019, Uber announced a 3rd generation version of its self-driving car and will start testing the new car on public roads in 2020.[126]

In January 2020, the National Science & Technology Council and the United States Department of Transportation released "Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0 (AV 4.0)". AV 4.0 builds upon Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0) and expands the scope to 38 relevant United States Government (USG) components that have direct or tangential equities in the safe development and integration of AV technologies.[127]

4.5.2.2 Mainland China

In July 2017, Internet giant Baidu announced that it was partnering with various companies in the self-driving car space. Taking a leading role in the development of self-driving cars in Mainland China and beyond, Baidu is working with automaker BMW to develop and test autopilot technology. Every year, there is an autopilot competition, and testing grounds are already operating in places like Shanghai and some cities in Anhui and Zhejiang provinces. Baidu offered a free software-controlled vehicle through a project called Apollo in 2017.[128] By making the "brain" of a self-driving car available to any party, the Apollo project could help Mainland China's young automakers rapidly get up to speed and create new innovations. Baidu also unveiled a broad self-driving car alliance in July 2017, reporting that it aimed to get such vehicles on the road in Mainland China by 2019. In 2019, Baibu has successfully launched self-driving robotaxi service for general pubic in Hunan Involving an initial fleet of 45 autonomous cars, the Baidu service will start on 50-kilometre-long open roads before gradually expanding.[129]

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124 *ArsTechnica, Intel reveals it has been working with Google on self-driving cars since 2009, 2017, retrieved from https://arstechnica.com/cars/2017/09/waymos-autonomous-vehicles-are-powered-by-intel/*
125 *BBC, Uber and Volvo strike deal for 24,000 self-drive cars, 2017, retrieved from http://www.bbc.com/news/technology-42055841*
126 *The Verge, Uber debuts a new self-driving car with more fail-safes, 2019, retrieved from https://www.theverge.com/2019/6/12/18662626/uber-volvo-self-driving-car-safety-autonomous-factory-level*
127 *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0 (AV 4.0), 2020, retrieved from https://www.transportation.gov/sites/dot.gov/files/2020-02/EnsuringAmericanLeadershipAVTech4.pdf*
128 *Nikkei Asian Review, Toyota to join Baidu's self-driving platform Apollo, 2019, retrieved from https://asia.nikkei.com/Business/Companies/Toyota-to-join-Baidu-s-self-driving-platform-Apollo*
129 *SCMP, Baidu launches self-driving robotaxi service for general public in Hunan, 2019, retrieved from https://www.scmp.com/tech/innovation/article/3030608/*

Mainland China has been catching up in the global race to develop self-driving cars, helped by supportive national regulations and by Beijing's desire to shift to an economy driven by hi-tech and consumer sectors rather than heavy industry and low-end manufacturing.[130] Between 2026 and 2030, Chinese authorities plan to place some type of automated or assisted driving system in every vehicle in the market. The sheer commercial potential of these impending technological developments explains Mainland China's overwhelming interest in bringing these projects to life.[131]

Figure 4-33 One of Baidu's experimental self-driving cars[132]

UISEE is another pioneer in commercialisation of self-driving technologies in Mainland China, with the company presenting a fully-autonomous vehicle at CES in Las Vegas in 2017. UISEE self-driving vehicles are equipped with a large number of perception components and employ advanced deep learning algorithms which fuse data from stereo cameras, surrounding cameras, millimetre-wave radars, laser scanners and ultrasonic sensors. These algorithms incorporate this data into planning and decision-making components which combine prediction, self-learning and knowledge-based expert systems which aim to deliver a safe, comfortable driving experience. UISEE has developed several product prototypes includes shuttles or sightseeing buses, which will be used for short-distance commutes in relatively closed environments. They have tested these shuttles at Guangzhou Baiyun International Airport. They entered trial operations in the second half of 2017. In 2019, after more than two years of R & D testing and trial operation, UISEE cooperated with Hong Kong International Airport to enable unmanned logistics vehicles at the airport to provide luggage transportation services for passengers.[133]

130 *SCMP, Baidu investigated after CEO tests driverless car on Beijing roads, 2017, retrieved from http://www.scmp.com/news/china/society/article/2101552/baidu-investigated-after-ceo-tests-driverless-car-beijing-roads*

131 *SCMP, China accelerates towards a driverless future as Hong Kong stalls, 2017, retrieved from http://www.scmp.com/comment/insight-opinion/article/2116900/china-accelerates-towards-driverless-future-hong-kong-stalls*

132 *MIT Technology Review, The Self-Driving Project That Could Help China Leapfrog the West, 2017, retrieved from https://www.technologyreview.com/s/608229/chinas-plan-to-take-over-all-self-driving-cars/*

133 *CMN, UISEE Secures Funding From Bosch, 2020, retrieved from https://www.chinamoneynetwork.com/2020/02/28/chinese-self-driving-firm-uisee-secures-funding-from-bosch*

Figure 4-34 A UISEE autonomous vehicle at CES 2017[134]

In view of the governmental policies, in May 2018, the three ministries and commissions of the Ministry of Industry and Information Technology, the Ministry of Public Security and the Ministry of Transportation jointly issued the "Intelligent Connected Vehicle Road Test Management Specification (Trial)", which is a guidance document for various specific organisations to conduct intelligent connected car road test work. So far, 16 self-driving car test sites have been established in Beijing, Shanghai, Chongqing, Wuxi and other places, which has laid the foundation for achieving a higher level of autonomous driving at an early date. In 2019, the 16 test areas jointly initiated signed an initiative, focusing on the safety of intelligent connected vehicles, promoting the coordinated development of vehicles and roads, simplifying the testing process, improving evaluation efficiency, and achieving data sharing and mutual recognition of results further improve the level of intelligent connected car test services in China.[135]

4.5.2.3 South Korea

South Korea has opened a four-lane highway section of its 3.45 million square-foot self-driving car testing facility known as “K-City”. K-City, a 5G-based autonomous vehicle testing center, located in Hwaseong, Gyeonggi, was opened at the end of 2018.[136] The initial aim for South Korea was to make a mark in the realm of self-driving vehicles by deploying autonomous vehicles which used HD mapping technology at 2018 Winter Olympics at Pyeongchang, shuttling visitors and athletes between Seoul and the Olympic site, a distance of about 125km. The hope was that the highway’s opening would support the government’s plans to make vehicles with Level 3 autonomy commercially.[137]

The Ministry of Land, Infrastructure and Transport of South Korea has released safety standards to operate Level 3 (partially autonomous) self-driving vehicles on Oct.29, 2019.[138]

The South Korean government plans fully autonomous driving by 2024 so the government shall prepared the communications, road and traffic infrastructures required for autonomous driving and put level 4 autonomous driving to commercial use on major roads in 2027 instead of 2030.

The government aims to put complete self-driving to commercial use three years ahead of schedule by working on level 3 and level 4 at the same time. Related systems such as insurance systems and vehicle performance

134 *CKGSB, UISEE Finds a Shortcut for Driverless Cars, 2017, retrieved from http://knowledge.ckgsb.edu.cn/2017/06/19/automobile-industry/uisee-technology-finds-shortcut-driverless-cars/*

135 *Ministry of Industry and Information Technology of the People’s Republic of China, 智能網聯汽車測試區交流研討會在京召開, 2019, retrieved from http://www.miit.gov.cn/newweb/n1146290/n1146402/n1146440/c7482742/content.html*

136 *Invest KOREA, K-City, Supporting Development of 5G-based Self-driving Technologies, Feb 2019, retrieved from http://m.investkorea.org/m/published/zone.do?mode=view&articleNo=479961&article.offset=0&articleLimit=10.*

137 *Futurism, South Korea Built a “City” to Test Self-Driving Cars, 2017, retrieved from https://futurism.com/south-korea-built-city-test-self-driving-cars/*

138 *The Ministry of Land, Infrastructure & Transport, 2019, retrieved from http://www.molit.go.kr/english/USR/BORD0201/m_28286/DTL.jsp?id=eng_mltm_new&mode=view&idx=2863*

evaluation will be introduced by 2024 while telecom, traffic control and road infrastructures are prepared along with precise maps. Also, an open future car industry ecosystem will be established by 2030 based on a private-sector investment of 60 trillion won, including two-thirds from Hyundai Motor Group.[139]

South Korean automaker Hyundai has begun a pilot program to testing autonomous vehicles on December, 2019.[140]

Figure 4-35 Seoul and Hyundai set to begin testing self-driving cars on city roads

4.5.2.4 Singapore

The government of Singapore is determined to make the small country a global pioneer of the self-driving vehicles (SDVs) industry. In February 2017, the Ministry of Transport introduced a series of Autonomous Vehicle Rules, or "AV Rules", for prospective trials of SDVs. With the amendment to the Road Traffic Act, the Singaporean law now recognises that motor vehicles don't require human drivers, making it the first world country to widely adopt autonomous driving.[141] Also, the ministry limited the regulatory sandbox for AVs to 2022, but the Ministry will consider enacting more permanent legislation or return to Parliament to further extend the period of the sandbox.[142]

Singapore has been pushing hard on AV development. The Centre of Excellence for Testing and Research of Autonomous Vehicles (CETRAN) at Nanyang Technological University was launched on November 2017, which has a test town for driverless vehicles complete with traffic lights, bus stops, skyscrapers and a rain-making machine to offer realistic testing conditions.[143]

In addition to this, it is also planning real-world field tests with driverless buses and shuttles in three areas (Punggol, Tengah and the Jurong Innovation District) for off-peak and on-demand commuting from 2022, and it is working with the Netherlands on an international standard for AVs.[144]

139 *South Korea Aiming to Complete Infrastructure for Level 4 Autonomous Driving within Five Year, 2019, retrieved from http://www.businesskorea.co.kr/news/articleView.html?idxno=37002*
140 *Seoul And Hyundai Set To Begin Testing Self-Driving Cars On City Roads, Nov.23, 2019, retrieved from https://interestingengineering.com/seoul-and-hyundai-set-to-begin-testing-self-driving-cars-on-city-roads*
141 *CIO Daily, How Singapore is driving the development of autonomous vehicles, 2019, retrieved from https://www.cio.com/article/3294207/how-singapore-is-driving-the-development-of-autonomous-vehicles.html*
142 *Ministry of transport, 2017, retrieved from https://www.mot.gov.sg/news-centre/news/Detail/Opening%20Speech%20by%20Second%20Minister%20for%20Transport%20Ng%20Chee%20Meng%20for%20the%20Road%20Traffic%20(Amendment)%20Bill%20Second%20Reading/*
143 *Land Transport Authority, Autonomous Vehicles, retrieved from https://www.lta.gov.sg/content/ltagov/en/industry_innovations/technologies/autonomous_vehicles.html*
144 *Opengov, Singapore ranks second globally in Autonomous Vehicle Readiness report, 2019, retrieved from https://www.opengovasia.com/singapore-ranks-second-globally-in-autonomous-vehicle-readiness-report/*

All of western Singapore will become a test bed for self-driving vehicles as the move towards autonomous mobility goes into overdrive. This sets the stage for companies to test their AVs in neighbourhoods such as Bukit Timah, Clementi and Jurong, with the expanded test bed covering more than 1,000km of public roads. The Land Transport Authority decided to expand the test bed as companies wanted the chance to conduct tests in a wider range of traffic scenarios and road conditions. This will support the robust testing of AVs' capabilities to provide inter-town services and longer-haul journeys in a safe manner, and pave the way for the planned pilot deployment of AVs in the early 2020s.[145]

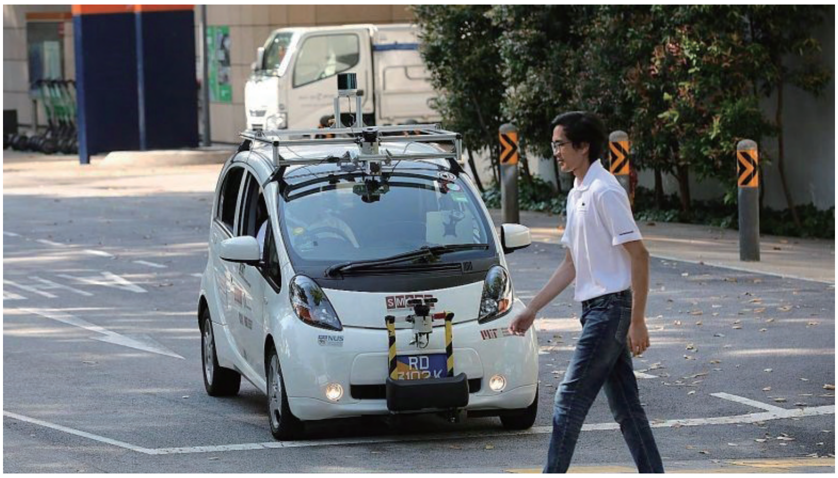

Figure 4-36 A self-driving electric vehicle being tested on the road in University Town at the National University of Singapore

4.5.2.5 The situation in Hong Kong

In the Smart City Blueprint Consultancy Study Report, published by the government's Innovation and Technology Bureau in June 2017, one of the many strategies announced included "Facilitating trials of autonomous vehicles in the West Kowloon Cultural District and other areas, as appropriate".[146] However, autonomous driving in Hong Kong is still very much in the preliminary stages. Hong Kong's first driverless car (Figure 4-36) was developed by Hong Kong University of Science and Technology (HKUST) researchers in 2017, which equipped a golf cart with an autopilot system that senses the external environment.

Figure 4-37 Tong F Chan, president of HKUST, sits in the university's driverless car[147]

145 *The Straitstimes, Western Singapore set to become test bed for self-driving vehicles, 2019, retrieved from https://www.straitstimes.com/singapore/transport/western-spore-set-to-become-test-bed-for-self-driving-vehicles*
146 *Innovation and Technology Bureau, Hong Kong Smart City Blueprint, 2017, retrieved from https://www.smartcity.gov.hk/*
147 *SCMP, Hong Kong's first driverless car forced to test in mainland China, 2017, retrieved from http://www.scmp.com/news/hong-kong/economy/article/2117660/first-driverless-car-built-hong-kong-hits-road-block*

Hong Kong does not have regulation governing for EVs which use autonomous driving functions. In the case of Tesla, only assisted steering, lane changing and auto parking function have so far been cleared for use after evaluation by Transport Department (TD). The “summon” function, which navigates a car into or out of a parking space by remote control, is not allowed. Meanwhile, assisted steering and lane change functions can only be used on roads with a central divider and a speed limit of 70 km per hour or above. Tesla's Autopilot function is disabled on most urban streets in Hong Kong, with drivers obligated to wait until they are on highways or in tunnels before turning on Autopilot. Tesla vehicles are also designed to require drivers to rest their hands on the steering wheel at all times.

Hong Kong Science and Technology Parks Corporation (HKSTP or “Science Park”) has established a smart mobility ecosystem in 2017 which brings together tech start-ups located in Science Park and automotive companies like Scania and Inchcape to catalyse smart mobility initiatives such as autonomous self-driving vehicles. However, to run an autonomous vehicle pilot project in Science Park, a movement permit for the vehicles is required by the Transport Department. The pilot project’s dates and details of the routes have to be submitted to the Department for approval.[148]

With "autonomous driving" becoming a reality, APAS and HKPC are strengthening their R&D efforts to help Hong Kong companies explore new business opportunities arising from smart mobility. In order to help local industries seize such opportunities, APAS has acquired its autonomous-ready vehicle in 2018 with the support of the Innovation and Technology Commission (ITC). It serves as an autonomous R&D platform for the future local development and application.

Figure 4-38 (From left to right) Dr David Chung, Acting Secretary for Innovation and Technology; Mr Willy Lin, Chairman of HKPC and Mr Mohamed D. Butt, Executive Director of HKPC, with APAS autonomous R&D platform in APAS R&D Centre Showcase 2018

In November 2019, to further promote the development of Autonomous Vehicle (AV) technology in the city, TD has set up the Technical Advisory Committee on the Application of Autonomous Vehicle Technologies in Hong Kong. The Committee, comprising representatives and experts from the trade and relevant research and development institutes, will explore how best to draw up an appropriate regulatory framework for AVs. TD will work in close collaboration and liaison with the trade and make reference to local experience of trials of AV technology when contemplating the long term regulatory framework with necessary legal backing.[149] However, the Government has so far restricted such vehicles from operating on roads in the territory. The permits for

148 *Computer World HK, HKSTP and CUHK unveil smart region pilots, 2017, retrieved from https://www.cw.com.hk/smart-city/hkstp-and-cuhk-unveil-smart-region-pilots*

149 *HKSAR Press release, Facilitating the application of information systems and development of autonomous vehicles, retrieved from https://www.info.gov.hk/gia/general/202001/15/P2020011500226.htm*

conducting trials of autonomous vehicles on Hong Kong roads should be applied on a case-by-case basis[150].

4.5.3 Future development

4.5.3.1 Enabling the development of technology

Operating and conducting all dynamic driving tasks without the input of human drivers means that autonomous vehicles must be absolutely dependent on reliable and secure technology. However, the widespread use and adoption of fully autonomous vehicles first requires a number of important and inter-related challenges to be solved. These are listed below.

1) Both technology and business models have yet to become mature
While technological experts are in a race to develop a working autonomous vehicle, the ideas regarding how these vehicles will be used are remarkably undeveloped. What roles will autonomous vehicles play in future transportation? How will users pay for transportation? Will users pay for services, or will they own the vehicles? If ridesharing companies can “commoditise” automobiles such that consumers no longer care what type of vehicle will take them from point A to point B, the majority of consumers will no longer purchase cars and only spend their money on ridesharing services instead. This will radically change the sets of profit pools across the entire automotive industry.[151]

2) Regulation and legislative framework
The presence of an appropriate regulatory and legislative framework is critical to the sustained success of autonomous vehicles. A stable regulatory environment allows companies to plan early and avoid making risky investments in ideas that could face legal challenges further down the road. Such an environment also builds the confidence of organisations and citizens in autonomous vehicles. On the path to creating an appropriate regulatory and legislative framework, testing is key to fully understanding the opportunities and risks associated with autonomous vehicles. Drivers will also need to be retrained and retested and as a result, education for drivers will need to be radically overhauled.

3) Changes to insurance
Autonomous vehicles will present a number of particularly complex problems for the insurance sector. First, insurance providers will need to design products that are suitable for owners and operators of autonomous vehicles. They will also have to cater to the users of new mobility services. At the moment, these providers are comparatively immature when it comes to assessing the risks of autonomous vehicles. Given the array of potential new uses for autonomous vehicles, there will be new vehicle users who were not previously considered eligible to drive. Insurers will have to assess how to cover these new risks.

4) Investment in infrastructure
The rollout of fully autonomous vehicles is related to two basic infrastructure requirements: road infrastructure and telecoms infrastructure. First, better maintenance of road infrastructure is fundamental, as this will allow autonomous vehicle technology to read the road. Second, fully connective data service coverage across the road network is essential. Meeting these requirements will necessitate a significant increase in infrastructure investment.[152]

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150 Transport Department, Guidance Notes on the Trials of Autonomous Vehicles, 2019, retrieved from https://www.td.gov.hk/filemanager/en/content_4808/guidance%20notes%20on%20the%20trials%20of%20autonomous%20vehicles%20eng.pdf

151 TechCrunch, Business models will drive the future of autonomous vehicles, 2017, retrieved from https://techcrunch.com/2017/08/25/business-models-will-drive-the-future-of-autonomous-vehicles/

152 PA Consulting Group, How long is the road to driverless vehicles?, 2017, retrieved from http://www2.paconsulting.com/CAV-Report-UK_Nordics-Report.html?_ga=2.57445098.1108061862.1515999998-1782367202.1515999998

4.5.3.2 Autonomous vehicles development in Hong Kong

According to the "Report of the Consultancy Study on the Smart City Blueprint for Hong Kong", conducted by PricewaterhouseCoopers Advisory Services Hong Kong Limited (PwC), despite the fact that autonomous vehicles pilot projects are being conducted at Hong Kong International Airport, Science Park and the Lok Ma Chau Loop, and despite the fact that the Road Traffic Ordinance is being revised; all these are planned to conclude between 2021 and 2025. The fact is that policies related to autonomous vehicles in Hong Kong are far behind other international cities.[153] The policy makers should prioritise launching more pilot projects in different locations around Hong Kong and speed up modifications related to autonomous driving.

4.6 Views and recommendations

Recommendation 8: Support for and testing of emerging EV technologies

The policy makers can provide financial incentives and testing facilities for power companies, charging service providers, telecommunications service providers, open data providers, property management offices, universities, R&D institutes, EV user groups and other stakeholders. These incentives will help harmonise common targets and goals, and create strategies and road maps for the development of emerging EV technologies in Hong Kong; as well as review the current regulations, obsolete or out-dated regulations and seek ways to set up new regulations and a legislative framework for new EV technologies.

The policy makers can also provide funding support for the test bedding of advanced and emerging EV technologies in Hong Kong that can hasten the pace of commercialisation and encourage increased investment from the private sector.

In addition, the policy makers can support the deployment of a 5G network and set up a common platform for data sharing among developers, manufacturers and other stakeholders which will support the development of V2X technologies and autonomous driving in general.

153 *PWC, Report of Consultancy Study on Smart City Blueprint for Hong Kong, 2017, retrieved from https://www.smartcity.gov.hk/report/full/*

CHAPTER 5: TALENT DEVELOPMENT TO SUPPORT EV MAINTENANCE AND SERVICE

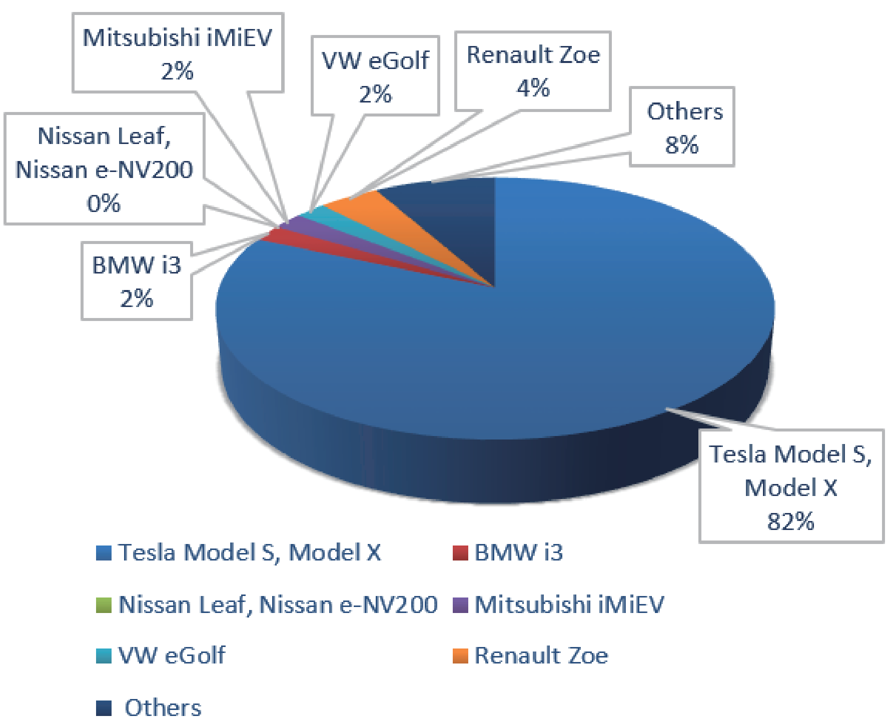
5.1 Overview of the Hong Kong situation

Currently, EV maintenance and repair services are mainly provided by manufacturers and authorised dealerships. The mechanics who are qualified to repair and maintain different brands of EVs work for their respective dealerships and manufacturers. On the other hand, mechanics working at independent service garages do not have sufficient knowledge, experience or tools to provide EV maintenance and repair services to EV owner at the moment. A person wanting to buy a vehicle who is considering an EV must accept that their vehicle can only be maintained by mechanics working in dealerships or manufacturers, as there are currently no other service providers from which to choose.

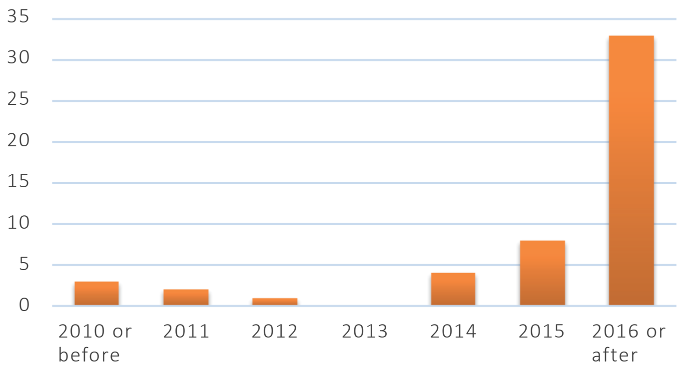
5.1.1 The opinions and experiences of EV drivers

APAS conducted a survey among EV drivers in 2017 about the EV maintenance and service situation in Hong Kong which was sent out by The Hong Kong Automobile Association (HKAA) to their members. The following charts illustrate some of the survey results.

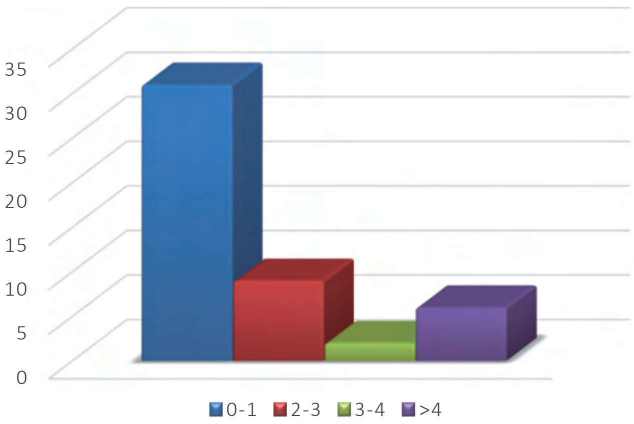
What model do you have?



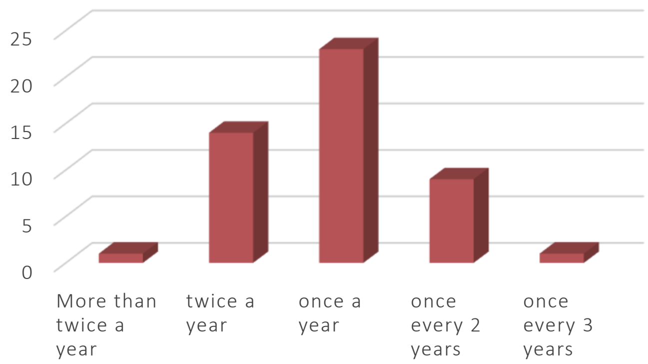
When your EV was made?



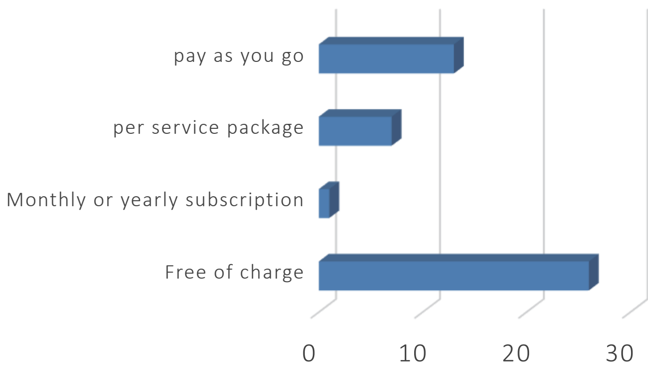
How many times has your car been serviced since you've owned it?



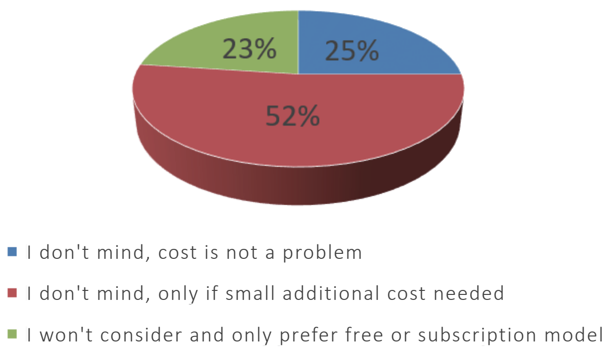
How frequently do you get your car serviced?



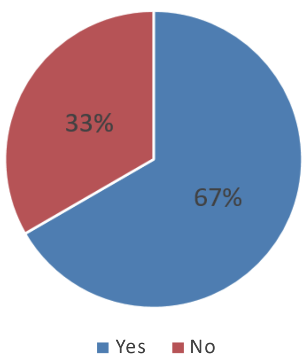
What type of service model are you on now?



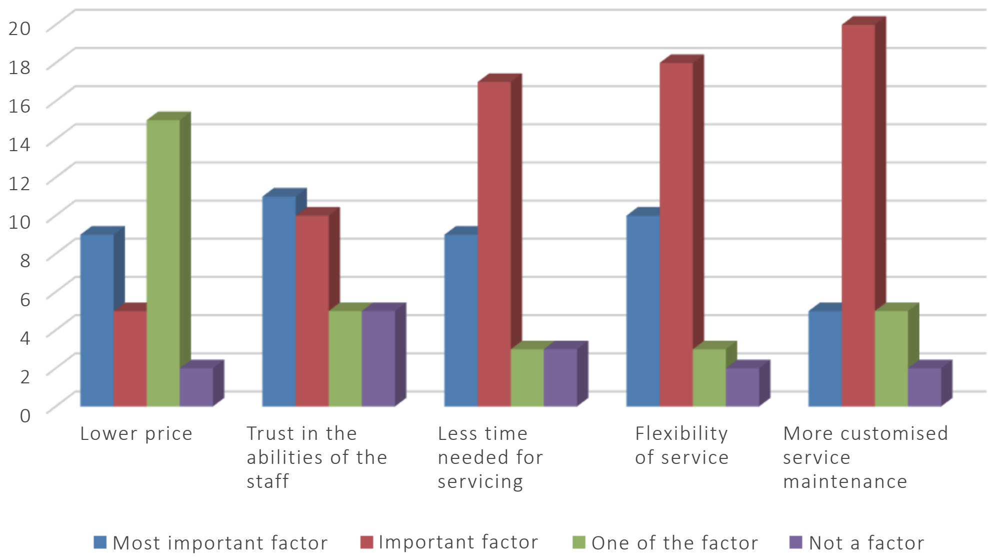
Would you mind paying more in exchange for shorter queuing or service time?



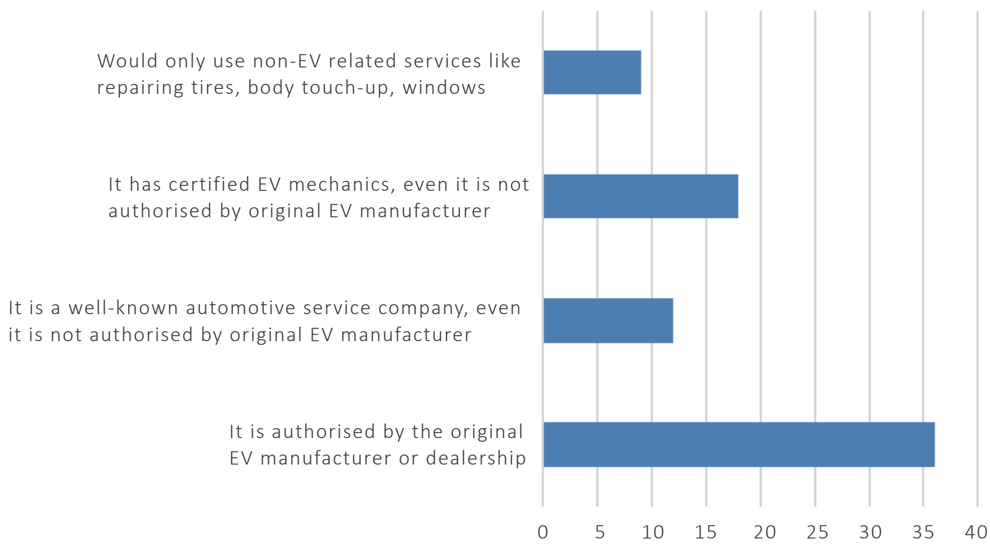
Would you expect to have an independent service garage, not by dealership?



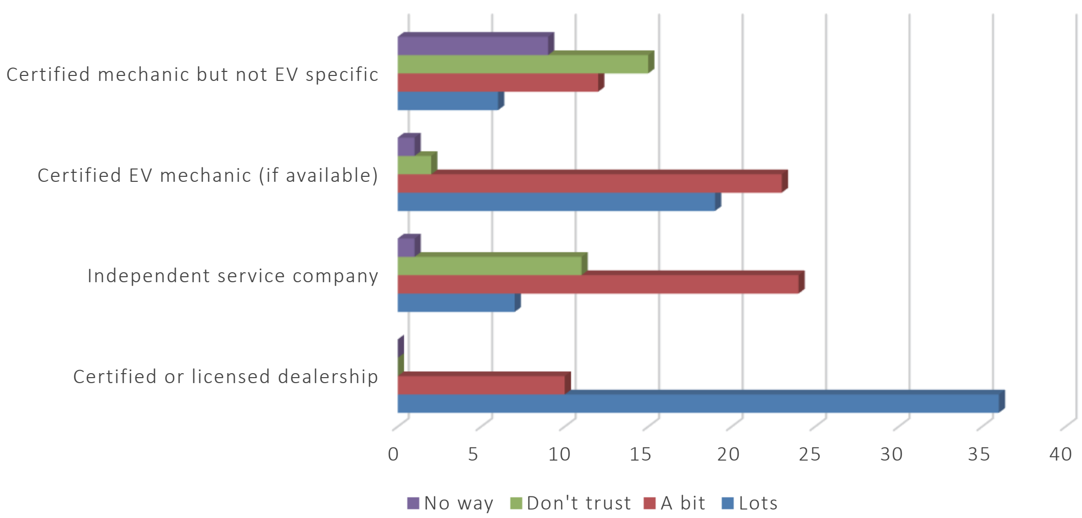
Rank the factors that would make you change to an independent service option



If there is independent service available, what would influence you the most to try a new garage?



How much do you trust each of the following maintenance approaches with your vehicle?



As the survey results illustrate, most EVs in Hong Kong are quite new. In general, Hong Kong EV dealerships provide a full maintenance and service package to their customers when they purchase a new EV. As most EVs are fairly new, they are mostly still under warranty and thus, the EV drivers surveyed have not yet encountered many maintenance or service issues.

When the warranty provided by these dealerships expires, many EV owners may want to switch to a qualified independent service garage which can carry out EV servicing and repair. The EV owners have the expectation that these independent service garages will save their time and money in contrast to having to take their vehicle back to the dealership whenever there is a problem. They also expect that these garages will be able provide more customised, convenient and flexible servicing and repair for their EVs. One of the important factors involved in EV owners trusting and selecting an independent service garage is that it should be both certified and authorised by the original EV manufacturer or dealership. The EV mechanics at this garage must also be trained and qualified to carry out EV maintenance and service.

5.1.2 Dealerships' opinions and experiences

The initial cost of purchasing an EV is quite high, but the investment has been shown to pay off in the long run. EVs have fewer moving mechanical parts than Internal Combustion Engine (ICE) vehicles, which means that in general, EVs have a smaller number of components in need of regular maintenance and repair. Several EV dealerships were interviewed in the course of this study, as we solicited their opinions and comments on the EV maintenance and service situation in Hong Kong.

According to the interviewees, the following EV issues are usually handled by EV dealerships when they maintain or repair their customers' vehicles:

- High voltage traction battery pack and battery management system;
- Electric air conditioning system;
- Accessories which are not related to the EV drivetrain, for example, body, lights, windows, tires and others.

For commercial EVs in Hong Kong, the vehicle usage rates are very high. Dealerships therefore have to carry out regular maintenance diagnoses more frequently for commercial EVs than for non-commercial EVs. Dealerships need to perform major check-ups for commercial EVs approximately every two months; and minor check-ups are also needed in the months where major check-ups are not conducted. The difficulty of obtaining parts and accessories for replacement in a timely manner is one of the major problems faced by these dealerships; occasionally, they may need to wait as long as a few weeks for the necessary parts and accessories to arrive.

Currently, the cost of maintaining an EV is comparatively higher than the cost of maintaining a gasoline-powered or diesel-powered vehicle. It also takes longer to conduct regular check-ups or diagnosis problems in EVs. The primary reasons for this are a lack of experienced EV mechanics who can perform these tasks efficiently, and a lack of immediately-available parts and accessories for replacement. However, due to the relative simplicity of EVs, most dealerships agree that the maintenance and repair costs for EVs will decrease at some point in the future. Similarly, EV repair and maintenance times should also decrease in the future. The simplicity of the electric motor that drives most EVs means that it contains less moving parts, as compared to the hundreds of moving parts in an internal combustion engine. There are simply not as many parts in an EV motor that can wear out and, when they do, they will be relatively simple to replace or repair.

To maintain a typical EV in the future, according to various estimations, will cost about one-third of the current cost of maintaining a typical internal combustion engine vehicle. The bottom line is that EVs require, and will require, considerably less maintenance than gasoline-powered or diesel-powered cars.

Most EV dealerships generally agree that there should be more independent service garages on the market that can provide EV maintenance and service. Their existence will increase the popularity of EVs in Hong Kong, as EV owners will have more choice when it comes to maintaining and repairing their EVs. The prices will generally be more reasonable as well. EV drivers will also be able to avoid the current long reservation times and lengthy service periods at dealerships' service centres. The presence of a number of independent service garages that are able to provide EV maintenance and service should remove a major obstacle to EV adoption in Hong Kong and consequently increase the sale of EVs in Hong Kong. The dealers recommend that these independent service garages be qualified and certified for EV maintenance and service so that they offer good quality services. The mechanics at these garages must also be properly trained in the repair and maintenance of EVs.

5.1.3 Independent service garages' opinions and experiences

As the population of EVs in Hong Kong increases, many independent service garages foresee that an increasing number of EVs will need to be maintained and repaired in the coming years. They also believe that the demand for EV maintenance and service will be very high, as many new car buyers are now considering selecting EVs when buying a new car.

Hong Kong has a dearth of qualified mechanics who can provide maintenance service to EVs. At the same time, most of the qualified EV mechanics are trained by and work for authorised dealerships and manufacturers. At the moment, independent service garages do not have the capability to maintain and repair EVs, and only limited services can be provided to EV users.

Many Hong Kong independent service garages have plans to enter the EV maintenance and service market. However, most automobile mechanics who work for these independent service garages are under on-the-job training for conventional internal combustion engine vehicles. They do not have the knowledge or experience to maintain or repair an EV: they have not been trained to handle specialized parts and accessories like high-voltage traction battery pack, battery management systems, high-power electric motors and vehicle system controls, all key components of EVs. However tempting to state, the solution is not as simple as "ensure that more mechanics are qualified to serve EVs". The patented technologies used by different EV manufacturers are important assets to ensure their vehicles have a competitive edge. EV makers do not have any impetus or intention to disclose the blueprints, schematics and maintenance information of their vehicles to independent service garages. Besides, vehicles from different EV manufacturers require specific equipment, fixtures and tools to carry out diagnosis and service tasks. These EV manufacturers seldom give or sell their equipment and tools to independent service garages. Without this technical information or these tools from the EV manufacturers, it will not be easy for independent service garages to offer EV maintenance services.

A representative of one independent service garage commented that without the support of the EV manufacturers and the industry, it will be very difficult for them to enter the EV maintenance and service market. They are now trying to liaise with different stakeholders to work out a solution to the difficulties they are facing.

5.2 Talent development and support

In this section, we will explore the idea of talent development to support EV maintenance and service in Hong Kong and overseas.

5.2.1 EV maintenance and service training – overseas market cases

The US

Several certificate and associate degree programmes in automotive technology which have a particular focus on hybrid technology are available to EV technicians in the US. These programmes equip technicians with knowledge about diagnosing, maintaining and repairing electric and hybrid-electric vehicles.

Aspiring technicians can start their careers in the EV industry by enrolling in one-year certificate programmes or two-year associate degree programmes provided by community colleges or technical and vocational schools. For experienced technicians, some states like California offer Certified Electric Vehicle Technician (CEVT) training programmes, with the tuition fees often sponsored by the Government. In addition, the National Institute for Automotive Service Excellence (ASE) provides professional certifications that certify automotive technicians in several specialties, including alternative fuels and engine machinery.

These certifications and degrees can demonstrate automotive aptitude and also increase employment opportunities.

Asia
In Mainland China, the Government is enormously enthusiastic about pushing the EV industry forwards. While Mainland China has emerged as a leader in the manufacture and purchase of EVs, there is also a lack of qualified EV engineers which is beginning to cause constraints to the growth of the industry.

There are a number of measures which have been taken to attempt to solve this problem. Each year, a number of forums and seminars are held in Shanghai, Mainland China's primary Electric Vehicle International Demonstration City. Two of the most well-known of these are the Electric Vehicle Talent Training Seminar and the Electric Vehicle Core Technology Breakthrough and Innovation Forum. Most of these forums and seminars are sponsored by academic or public organisations like the Chinese Mechanical Engineering Society, the Chinese Association of Automation, the China Automotive Technology & Research Center and others.

A variety of training courses have also been developed in a collaborative way between the Government and the EV industry, like training for the Emergency Rescue of Electric Vehicle Accident by General Motor and the Shanghai Fire Services Department.

In addition, commercial training courses are plentiful in Mainland China. One of the most popular courses is the Electric Vehicle Training Service course offered by TUV SUD Greater China.

Europe
In the UK, various certificates are available to EV technicians. The Institute of the Motor Industry (IMI) accredits technicians with three levels of awards in the electrically-propelled vehicle branch and the hybrid EV branch. The accreditations covers hazard management, operation and maintenance, repair and replacement and others. The IMI has also approved several training centres to provide these courses, offering technicians across the country accreditation in all aspects of hybrid and EV systems.

Spain, the second-largest car manufacturer in Europe, has more than 100,000 students studying engineering disciplines related to car industry every year. Some colleges also provide master's degrees specifically for EVs, and the government has plans to put resources into promoting sustainable mobility. Graduates who are interested in the EV industry have many choices to be specialists in the industry, through programmes like the Master's of Hybrid and Electric Vehicle Engineering offered by the Technical University of Madrid, or the Electric Vehicle Master Plan launched by Barcelona City Council.

5.2.2 EV maintenance and service training offered by dealerships in Hong Kong

EV dealerships find that qualified EV mechanics and technicians are difficult to recruit in Hong Kong. Several dealerships have commented that the training institutions in Hong Kong cannot effectively supply a sufficient number of mechanics or technicians who can handle EV maintenance and service tasks. These dealerships thus have to train their EV mechanics through the overseas EV manufacturers or by other experienced staff. Some dealerships use a "train-the-trainer" approach to train their mechanics, with these dealerships sending their engineers to attend intensive training offered by the overseas EV manufacturers. These trained engineers then become trainers for local EV maintenance and repair service staff. In-house engineers and technicians with suitable automotive service knowledge and experience are recruited and put through on-the-job training to maintain and repair EVs.

These dealerships recommend that the policy makers should increase the intake for automotive courses offered by local training institutions, while the number of part-time courses for EV training should also be increased. The content of EV training courses should also be strengthened. All EV mechanics who are engaging in EV maintenance and service must be properly trained and certified; this will allow the proper representation of the unique skill sets required for EV servicing and provide the appropriate recognition to promote the professional identity of EV maintenance and repair personnel.

5.2.3 EV maintenance and service training in Hong Kong

Currently in Hong Kong, automotive training courses are mainly provided by the Hong Kong Institute of Vocational Education (IVE), the Pro-Act Training and Development Centre and Youth College.

IVE (Tsing Yi) offers a Higher Diploma in Automotive Engineering course, with the programme aiming to provide students with important theoretical knowledge as well as a useful range of employable and practical skills in automotive engineering. Close links with local industry and Mainland China ensure that the graduates will fulfil the evolving needs of the industry and the market.

Figure 5-1 The workshop in IVE (Tsing Yi)

The Pro-Act Training and Development Centre (Automobile) offers practical training in vehicle mechanics, maintenance and repair in a 4,000 square metre training set-up that simulates several real-life contexts. The cutting-edge facility provides hands-on instruction across a wide range of vehicles, including diesel and LPG engine operations and servicing. The Pro-Act Training and Development Centre (Automobile) provides the part-time automotive courses and offers practical training and support for full time Diploma of Vocational Education (DVE) programme run by Youth College, and helps students acquire knowledge and skills for further studies and employment.

Figure 5-2 The Pro-Act Training and Development Centre (Kwai Chung) workshop

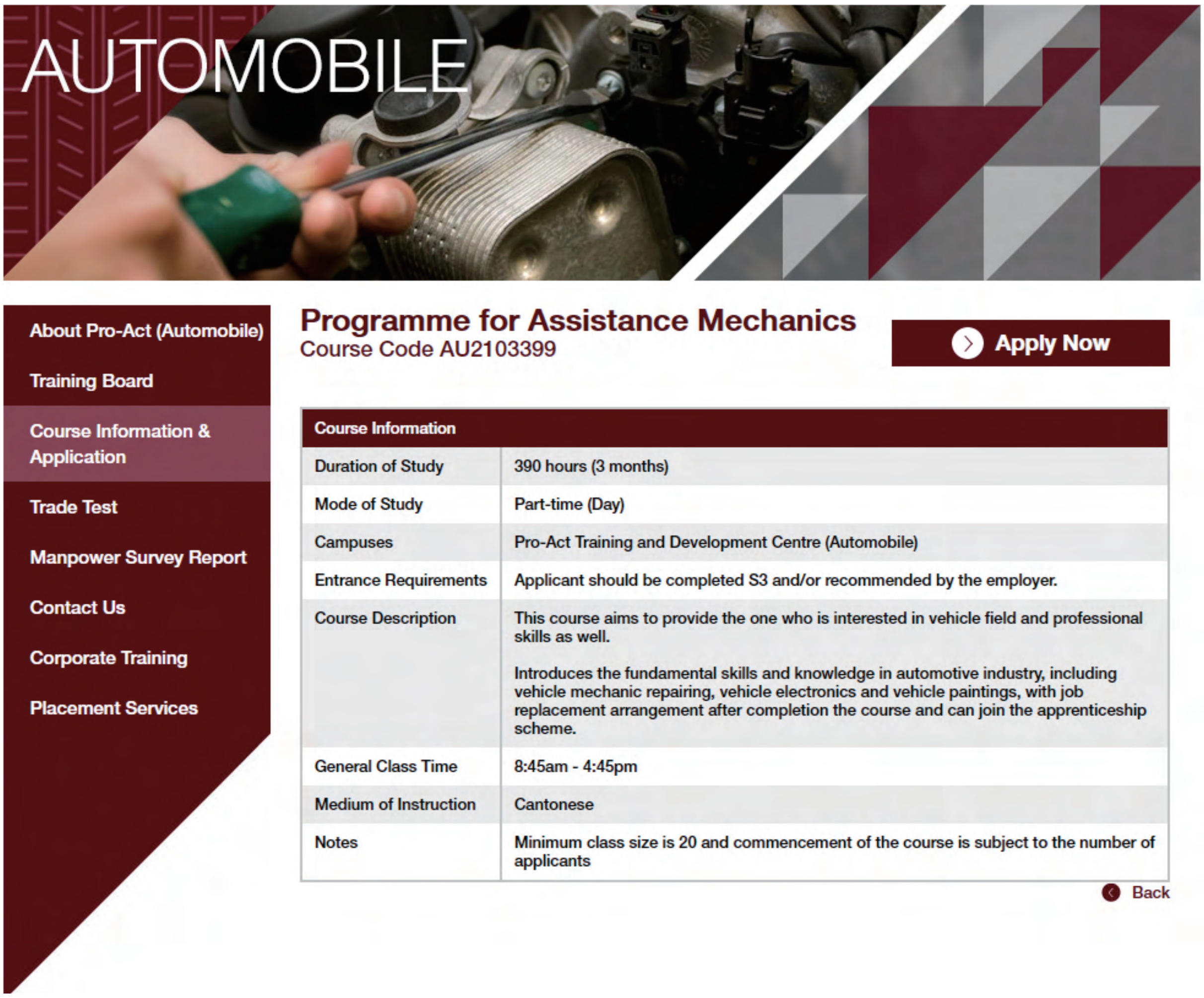
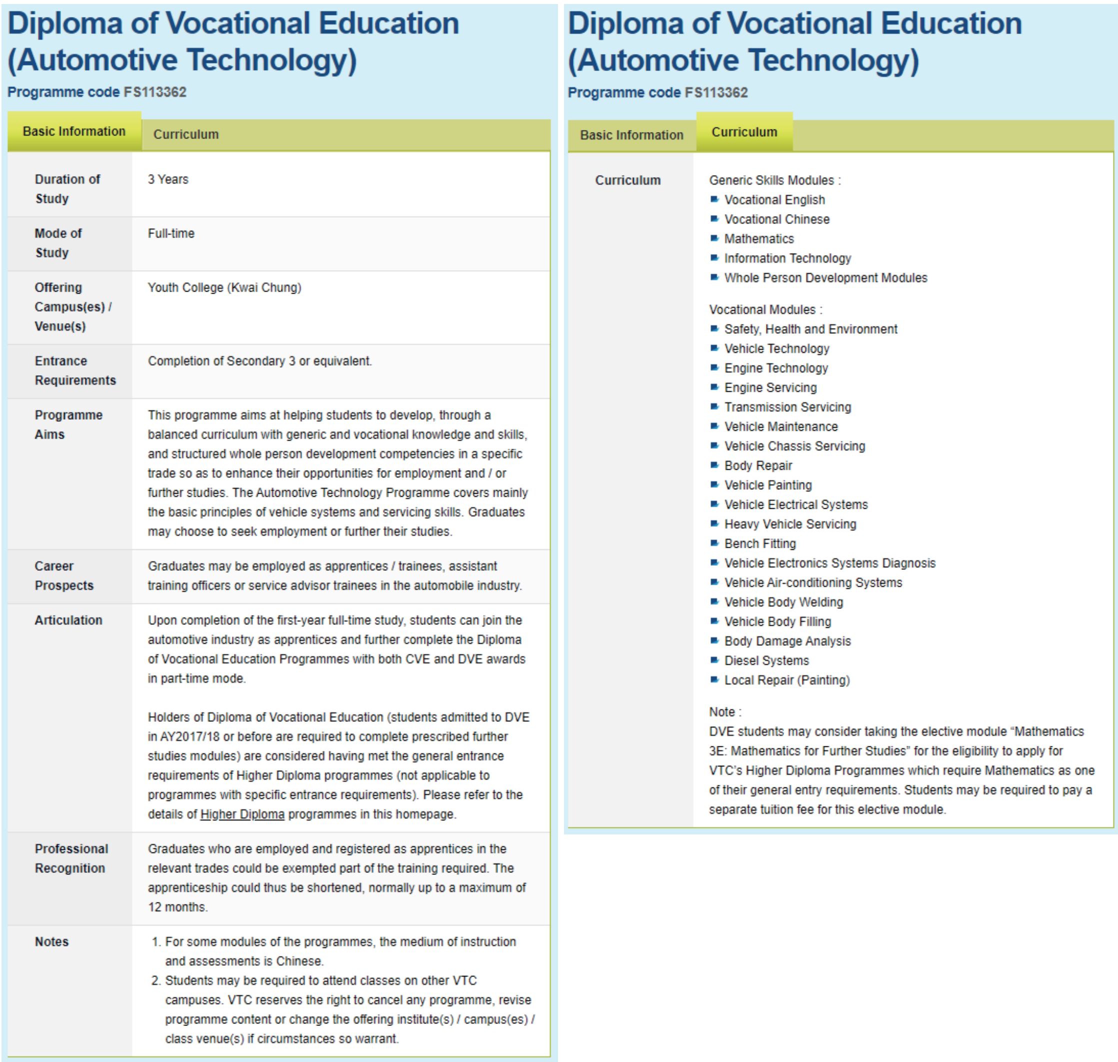


Figure 5-3 EV course offered by the Pro-Act Training and Development Centre (Automobile)[154]

154 ProAct, Centre and Programme, Automobile, retrieved from http://www.proact.edu.hk/proact/html/en/centres-and-programmes/automobile/information/course/course_190.html

Youth College in Hong Kong offers Diploma of Vocational Education (Automotive Technology) courses for secondary students who have completed Secondary 3 or 6. These courses aim to help students develop their abilities through a balanced curriculum with generic and vocational knowledge and skills and structured whole-person development competencies in a specific trade. The Automotive Technology Programme mainly covers the basic principles of vehicle systems and servicing skills. Graduates may choose to seek employment or further their studies. Graduates may be employed in the automobile industry as technician apprentices, assistant training officers or service advisor trainees.



Diploma of Vocational Education (Automotive Technology)

Programme code FS113362

Basic Information | Curriculum

Duration of Study	3 Years
Mode of Study	Full-time
Offering Campus(es) / Venue(s)	Youth College (Kwai Chung)
Entrance Requirements	Completion of Secondary 3 or equivalent.
Programme Aims	This programme aims at helping students to develop, through a balanced curriculum with generic and vocational knowledge and skills, and structured whole person development competencies in a specific trade so as to enhance their opportunities for employment and / or further studies. The Automotive Technology Programme covers mainly the basic principles of vehicle systems and servicing skills. Graduates may choose to seek employment or further their studies.
Career Prospects	Graduates may be employed as apprentices / trainees, assistant training officers or service advisor trainees in the automobile industry.
Articulation	Upon completion of the first-year full-time study, students can join the automotive industry as apprentices and further complete the Diploma of Vocational Education Programmes with both CVE and DVE awards in part-time mode. Holders of Diploma of Vocational Education (students admitted to DVE in AY2017/18 or before are required to complete prescribed further studies modules) are considered having met the general entrance requirements of Higher Diploma programmes (not applicable to programmes with specific entrance requirements). Please refer to the details of Higher Diploma programmes in this homepage.
Professional Recognition	Graduates who are employed and registered as apprentices in the relevant trades could be exempted part of the training required. The apprenticeship could thus be shortened, normally up to a maximum of 12 months.
Notes	1. For some modules of the programmes, the medium of instruction and assessments is Chinese. 2. Students may be required to attend classes on other VTC campuses. VTC reserves the right to cancel any programme, revise programme content or change the offering institute(s) / campus(es) / class venue(s) if circumstances so warrant.

Diploma of Vocational Education (Automotive Technology)

Programme code FS113362

Basic Information | Curriculum

Curriculum

Generic Skills Modules :
- Vocational English
- Vocational Chinese
- Mathematics
- Information Technology
- Whole Person Development Modules

Vocational Modules :
- Safety, Health and Environment
- Vehicle Technology
- Engine Technology
- Engine Servicing
- Transmission Servicing
- Vehicle Maintenance
- Vehicle Chassis Servicing
- Body Repair
- Vehicle Painting
- Vehicle Electrical Systems
- Heavy Vehicle Servicing
- Bench Fitting
- Vehicle Electronics Systems Diagnosis
- Vehicle Air-conditioning Systems
- Vehicle Body Welding
- Vehicle Body Filling
- Body Damage Analysis
- Diesel Systems
- Local Repair (Painting)

Note :
DVE students may consider taking the elective module "Mathematics 3E: Mathematics for Further Studies" for the eligibility to apply for VTC's Higher Diploma Programmes which require Mathematics as one of their general entry requirements. Students may be required to pay a separate tuition fee for this elective module.

Figure 5-4 The Diploma of Vocational Education (Automotive Technology) course offered by Youth College[155]

As discussed earlier, in Hong Kong, the number of EVs is still very small compared with diesel-powered and gasoline-powered vehicles. While the maintenance and service of diesel-powered and gasoline-powered vehicles focuses mainly on mechanical parts and internal combustion engines, EV maintenance and service requires a set of new and specific skills, including knowledge of power electronics, battery management systems, electrical power systems and electric motors. The current EV repair and maintenance service industry workforce needs to be trained in a wide array of fit-for-purpose and well-supported training curricula. However, the current education providers – IVE, Pro-Act and Youth College – only provide the foundation curricula for EV maintenance and service. The curricula for EVs mainly consists of introducing EV theory and technology, EV safety, precautions to be considered when repairing EVs, and the isolation techniques needed when handling high-voltage system in EVs.

155 *Vocational Training Council, Diploma of Vocational Education (Automotive Technology), retrieved from http://www.vtc.edu.hk/admission/en/programme/fs113362-diploma-of-vocational-education-automotive-technology/basic-information/*

The demand for conventional automotive mechanics who can maintain and repair diesel-powered and gasoline-powered vehicles is still high in Hong Kong, and automotive curricula still focus overwhelmingly on conventional vehicles. For the full-time automotive courses conducted by the above institutions, the total duration of EV subjects is less than ten per cent of the overall course duration. After completing the EV subjects and finishing the courses, students will only have acquired quite basic knowledge and techniques on how to handle EV maintenance and service. Institutions in Hong Kong do not offer advanced EV maintenance and service courses for the simple reason that at the moment there is a lack of demand. In addition, these institutions are in a difficult position, as they do not have the appropriate EV diagnosis tools or detailed service manual to provide more sophisticated and advanced training courses for their students, since EV manufacturers have their own proprietary diagnosis tools for their vehicles. It is recommended that EV manufacturers disclose the relevant information and provide the required tools to these institutions.

These institutions are in discussions to purchase some EV training tools from overseas to facilitate their teaching. They also have a initiated a “Student Industrial Attachment Programme”, which is a cooperative programme with local EV dealerships whereby students from these institutions work in these local EV dealerships for a short period to learn and develop specific EV maintenance and service skills, gaining hands-on EV maintenance experience. Several local dealerships have also donated EV parts and accessories, for example EV battery modules, to these institutions for teaching purposes.

Figure 5-5 EV battery modules donated to the institutions by local EV dealerships

5.3 Views and recommendations

The under supply of qualified EV mechanics and independent EV service garages in Hong Kong raises a number of concerns over convenience, cost and the safety of EVs. It is one of the biggest obstacles for car owners contemplating switching over to an EV.

In order to increase the number of qualified EV mechanics, institutions in Hong Kong should strengthen and enrich the EV training content in their automotive courses. Graduates from these institutions should be equipped with the necessary knowledge and techniques for EV maintenance and service. It is also recommended adding an EV service category to the “Voluntary Registration Scheme for Vehicle Mechanics”, as this will ensure that EV mechanics possess the necessary qualifications and experience to maintain EVs. All EV mechanics should be properly trained and certified so that their qualifications and competence will gain recognition. In addition, all EV manufacturers should release maintenance guides and the required maintenance tools to the training institutions.

The general opinion is that if more independent EV service garages are available, it will benefit the entire Hong Kong EV market. APAS has set up the EVSIG, the stakeholders will be able to share their insights and opinions on developing the EV maintenance and service industry in Hong Kong. Independent service garages should also proactively communicate the difficulties and hindrances they face in terms of EV maintenance and service to try to get support from other stakeholders in the group.

Recommendation 9: Fulfil the latest Specification of Competency Standards for EV training

The Qualifications Framework has updated the competency standards to cater for the future development of EV services. The latest version of "Specification of Competency Standards" (SCS) was released in May 2019.[156] The SCS for the automotive industry is mainly comprised of the competency standards required for the present operation and future development of the industry.

It is recommended that the automotive industry and training institutions should introduce training courses immediately to fulfil the EV competency standards as stated in the SCS. This will promote the professional identity for EV practitioners and improve the overall quality of EV maintenance and service.

Recommendation 10: Strengthen and enrich the content of EV training curricula

To fulfil the rising demand for EV maintenance and service in Hong Kong, it is recommended that the territory's educational institutions strengthen the EV training content of their automotive courses. To improve the skill sets of EV mechanics, these institutions should offer more advanced and more comprehensive EV maintenance and service courses to their students. In order to facilitate the teaching of these courses, it is also recommended that EV manufacturers provide them with the relevant EV diagnosis tools and detailed service manuals. These institutions should also purchase the most relevant and recent advanced EV training tools from overseas.

Furthermore, to increase the number of qualified EV mechanics, these institutions should provide more part-time EV maintenance and service courses for conventional automotive mechanics. These courses may help these mechanics migrate their maintenance skill sets from conventional vehicles to EVs. The institutions can also cooperate with local EV dealerships, arranging for their students to work in these local dealerships for short periods to learn and develop their EV maintenance and service skills, allowing them to gain hands-on EV maintenance experience from these cooperative programmes.

156 *Qualifications Framework, Automotive Industry, Specification of Competency, 2019, retrieved from https://www.hkqf.gov.hk/filemanager/automotive/common/scse/automotive/v2/Automotive_Eng_SCS_Version_2_2019-7-29.pdf*

CHAPTER 6: THE DECOMMISSIONING OF BATTERIES AND EVS

In 2019, there are 13,866 EVs for road use in Hong Kong as at end of December 2019, up from less than 100 EVs in the end of 2010.[157] As a result, the decommissioning of batteries and EV will also increase as time passes. The recycling and reuse of vehicle batteries and accessories are necessary if we are to protect the environment, however, recycling lithium ion batteries entails certain costs and potential waste. Giving a second life to these batteries can ensure that they are used efficiently and delay the disassembly and recycling processes.

6.1 Overview of the EV recycling process

6.1.1 Vehicle accessory recycle

When EVs are decommissioned, they contain many useful parts which can be reused. The lithium-ion (Li-ion) battery is the most costly part of an EV and has the most value for recycle and reuse. However, the other vehicle parts and accessories which are made from different materials such as plastic (bumpers, tires), metal (the vehicle body and motor), the auxiliary battery and others, are also worth recycling, as they will maximise the use of resources and protect the environment.

When recycling EV accessories, the first consideration is the ease with which the vehicle's structure can be dismantled. Many car manufacturers actually consider the ease of dismantling during the vehicle's design stage. Recycling companies then dismantle the accessories and classify them into different materials. After sorting the materials, they will be passed to shredding companies for shredding into smaller pieces. The materials can then be recycled and reused for other items.

6.1.2 Battery recycling

Most EV batteries were initially Nickel Metal Hydride (NiMH) batteries, the predominant chemical compound used in HEV batteries. The first wave of HEV NiMH batteries are now reaching the end of their lives. Next, Li-ion batteries, used in more recent EVs, will also be dismantled soon. Whether NiMH or Li-ion based batteries, a strong economic incentive for recycling exists, since valuable materials such as nickel, cobalt and lithium can be sorted and recycled.

In general, in order to extract the useful metals from Li-ion batteries, a recycling company typically dismantles a battery into its components and then reduces these components into either small pieces or powders. The various materials are sorted by a separation process and then put through a chemical treatment, like a hydrometallurgy treatment, to extract the rare metals. However, there is still plenty of room for Li-ion battery recycling methods to be improved.

157 *Environmental Protection Department, EV models in Hong Kong, 2019, retrieved from https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/promotion_ev.html*

6.1.3 Second life batteries

Most EVs require and use very high performance batteries. Once the capacity of these batteries declines below to 80 per cent, they are swapped out for new ones. However, these retired batteries still have many charge and discharge cycles left in them, making them useful for storage and other applications.

Second life applications can delay the disposal of batteries that still have energy storage value. Their potential applications include solar panel energy storage, wind power storage, UPS power packs and many others.

Before utilising a battery for a second life application, its quality has to be checked. A typical quality analysis is based on a components test and an analysis of the data stored in the battery management software. If more data is available, the battery's state of health can be determined more precisely. The methodology for checking and classifying a battery's decommissioning should be standardised to effectively identify the battery's quality which will enable it to be matched with the appropriate second life application.

6.2 Second life of EV batteries

6.2.1 The reuse challenge

The state of any individual battery's health is dependent on what they have been exposed to and how they have been treated over the course of their life thus far. The health of a battery pack as a whole depends on the health of each of the battery modules, which in turn are dependent on the health of the battery cells. To successfully re-use an EV battery and give it a second life means standardising the quality of used batteries and having procedures in place to maintain their safety.

Figure 6-1 Example of a battery cell, module and pack[158]

Second life batteries are a relatively new industry and business models are still developing. Although it is widely recognised that there is a large potential market, second life batteries still face many technical problems and challenges.

The current major challenges to giving Li-ion batteries a second life are:

- Difficulties in identifying the exact chemical composition of individual batteries;
- A lack of proper guidelines on the safe dismantling of battery packs;
- A lack of knowledge and information on the proprietary electronics of battery cells; and
- Fluctuations in the percentage of metals within batteries and fluctuations in the price of recycled metals.

6.2.2 Possible solutions and applications

Collecting and grouping EV batteries by model can minimise the effort involved in identifying batteries that have different chemical compounds. Recycling companies and automakers should work together to support the development of the second life battery business.

158 *Electric Cars Report, Samsung SDI Showcases New EV Batteries and Materials at Auto Shanghai 2015, retrieved from https://electriccarsreport.com/2015/04/samsung-sdi-showcases-new-ev-batteries-and-materials-at-auto-shanghai-2015/*

The global UL 1974 standard has been set up to guide second life battery developers towards the level of quality they need to meet. In addition, there are four China standards (GB/T33598-2017, Recycling of traction battery used in electric vehicle—Dismantling specification, GB/T34013-2017, Dimension of traction battery for electric vehicles, GB/T34014-2017, Coding regulation for automotive traction battery and GB/T34015-2017, Recycling of traction battery used in electric vehicle—Test of residual capacity), which were announced in July and August 2017. These four GB standards are designed to guide industry players to dismantle EV Li-ion batteries, standardise the coding of batteries during their manufacture which will facilitate the tracking of battery history, regulate the size of battery packs, and normalise inspection procedures for retired batteries to promote their use as second life batteries. A battery's State of Charge (SOC) and State of Health (SOH) can be inspected based on these guidelines, and similar quality batteries can be grouped together. Typical potential applications such as UPS or energy storage for solar plants can then be determined subject to the battery's quality.

6.3 Situation in different markets for second life battery recycling

North America

According to the Commission for Environmental Cooperation (CEC) based in North America, an organisation which aims to facilitate collaboration and public participation to protect the environment in North America, i.e. Canada, Mexico and the US. The market in North America for EVs has surged over the last 10 years and the supply of end-of-life batteries is expected to continue to increase.

A few key companies in North America have the technology and capacity to process NiMH and Li-ion batteries from EVs. These include Retrive, Inmetco, Glencore/Xstrata and RMC.

A new UL standard, UL 1974 deals with second life applications for batteries. It has been proposed that this standard be developed into an American National Standard, which will help address safety and performance testing issues for intended applications, as well as help create guidelines for removing grid connections, communication interfaces or electronic parts from the pack with destroying it.

Europe

When it comes to legislation pertaining to battery recycling, Europe is the undisputed leader. The European Batteries Directive, first adopted in 1991, sets clear targets on collection and recycling rates for all types of batteries. Umicore conducts a number of recycling activities in Europe. The French metal recycling company, SNAM (Societe Nouvelle d' Affinage des Metauz), processes up to 300 tonnes of Li-ion batteries annually. Euro Dieuze Industrie, another French company, specializes in battery recycling, including the recovery of lithium. In France, Recupyl treats spent batteries from HEVs, PHEVs, and EVs by using hydrometallurgy techniques.

Also in Europe, solar retail grid parity has been achieved. Recycling companies re-package retired batteries and use them in residential photovoltaic (PV) systems. Retired batteries store energy generated from solar panels, with consumers benefitting by paying less money to electric companies for power drawn from the electricity grid. Besides being integrated with solar systems, retired batteries can also be re-packaged and used with windmills to store electricity generated by wind power.

Japan

Nissan Motor Co. has partnered with Sumitomo Corporation to initiate a business plan to recover and resell used EV batteries. They have established a new joint venture company called 4R ENERGY Corporation to conduct research and field tests on the second life usage of Li-ion batteries that have been previously used in EVs. Nissan and Sumitomo have designated the second life use of Li-ion batteries as a "4R business", i.e. "reuse, refabricate, resell, recycle", with the aim of enhancing sustainability through an increase in renewable energy usage, as well as improving the overall value chain for the wider market.

In addition, Sumitomo Metal Mining (SMM) Corp. in Japan recycles used NiMH batteries from HEVs. Toyota Motor Corporation (TmC) is partnering with SMM to develop related businesses. Honda has also joined forces with Japan Metals and Chemicals (JMC) to develop a new process for extracting oxides containing rare-earth metals (mischmetal – an allow of rare-earth metals) from used NiMH batteries. Honda was given a permit for Li-ion battery recycling starting in the spring of 2017 in Japan.

Mainland China

Mainland China produces a lot of EVs in the world. As a result, retired batteries will become a big problem in the coming years. Hence, the Chinese government is actively pushing to reuse and recycle EV batteries. The government's announcement of four China standards (GB/T33598-2017, Recycling of traction battery used in electric vehicle—Dismantling specification, GB/T34013-2017, Dimension of traction battery for electric vehicles, GB/T34014-2017, Coding regulation for automotive traction battery and GB/T34015-2017, Recycling of traction battery used in electric vehicle—Test of residual capacity) is helping to develop guidelines for recycling companies to test and inspect retired batteries and re-package these battery for different applications. On the other hand, many recycling companies such as Brunp, GEM Co., Sound Group, Ganzhou Highpower and CATL have started Li-ion battery recycling businesses. However, most recycling companies are currently focusing on recycling raw materials from retired batteries rather than developing second life battery applications. However, these recycling companies are gradually expending more time on reusing retired batteries. For example, Optimumnano Recycling tried to build a 3MW energy storage system by using retired Lithium Iron Phosphate (LFP) batteries.

Hong Kong

The policy makers in Hong Kong is also encouraging the recycle and reuse of retired batteries. According to Environmental Protection Department regulations, retired batteries must be treated as chemical waste. Under the Waste Disposal (Chemical Waste) (General) Regulation, battery recycling companies should register as licensed waste collectors for chemical waste in order to conduct proper disposal, and are required to comply with the requirements of the Regulation on packaging, labelling, storage and trip tickets. At the moment, there are only four licensed chemical waste collectors who are able to handle waste batteries from EVs on EPD's authorised list.[159]

Furthermore, waste battery collectors only can send retired batteries to other countries for further treatment, like Japan, Korea and Singapore, since the lack of land in Hong Kong prevents the construction or implementation of chemical recycling processes.

In fact, the policy makers could take a more aggressive role the development of the battery recycling industry and promoting the value of second life batteries in general. In 2016, the "International Competition on Second Life for Retired Batteries from Electric Vehicles" was organized. The competition gave the public an opportunity to design and repack retired batteries in different ways that were suitable to the Hong Kong situation, giving people more insight into ways to extend the value of retired batteries and potential methods in which they could be reused.

Electrical and Mechanical Services Department (EMSD) has collaborated with APAS and HKPC to explore possible second life applications of retired EV batteries through proof-of-concept projects. APAS, EMSD and HKPC have developed a mobile EV charger prototype (Figure 6-2) that contains 2 sets of retired batteries from 2 EV models (Nissan Leaf and Mitsubishi i-MiEV). The Retired EV Battery Mobile Charger is equipped with 3 different industrial electric outlets and 1 set of EV medium charger outlet. Apart from serving for EV charging, the mobile EV charger worked smoothly in a real operation to serve as a temporary power supply during electricity suspension at the Government Out-patient Clinic in Chai Wan in late 2019.

159 *Environmental Protection Department, Chemical Waste Collectors - Waste Batteries from Electric Vehicles, retrieved from https://cd.epic.epd.gov.hk/EPICDI/chemicalwaste/download/*

Figure 6-2 Retired EV Battery Mobile Charger

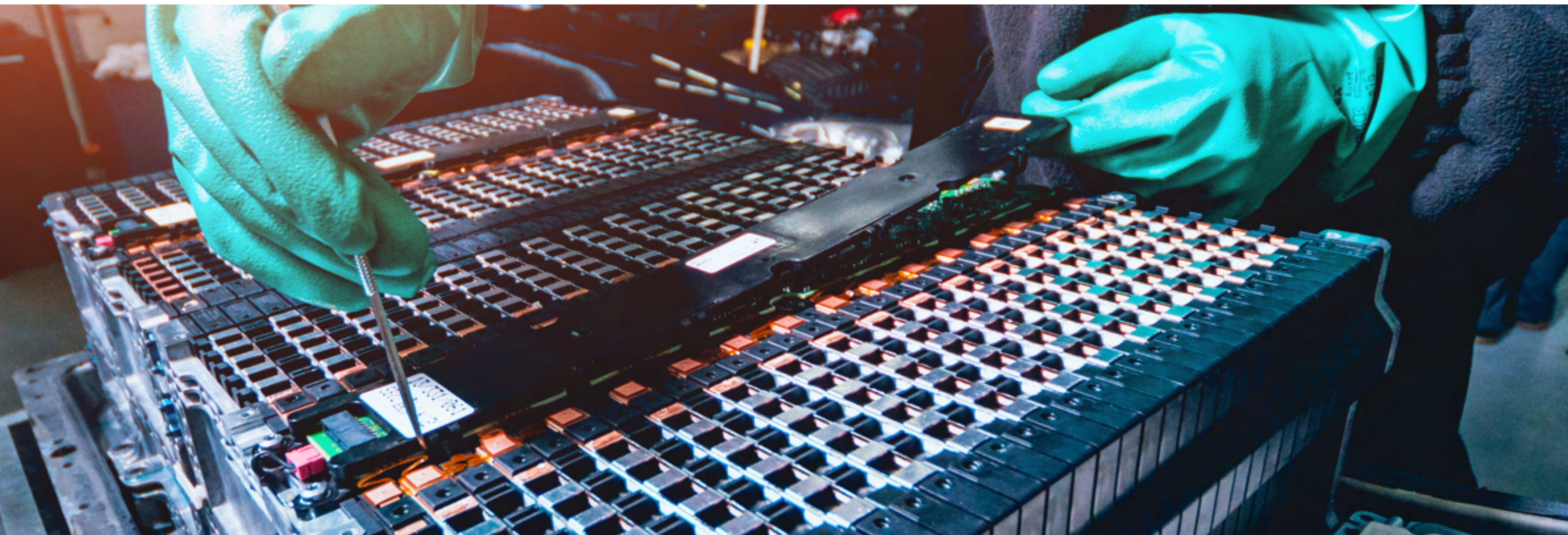
6.4 View and recommendations

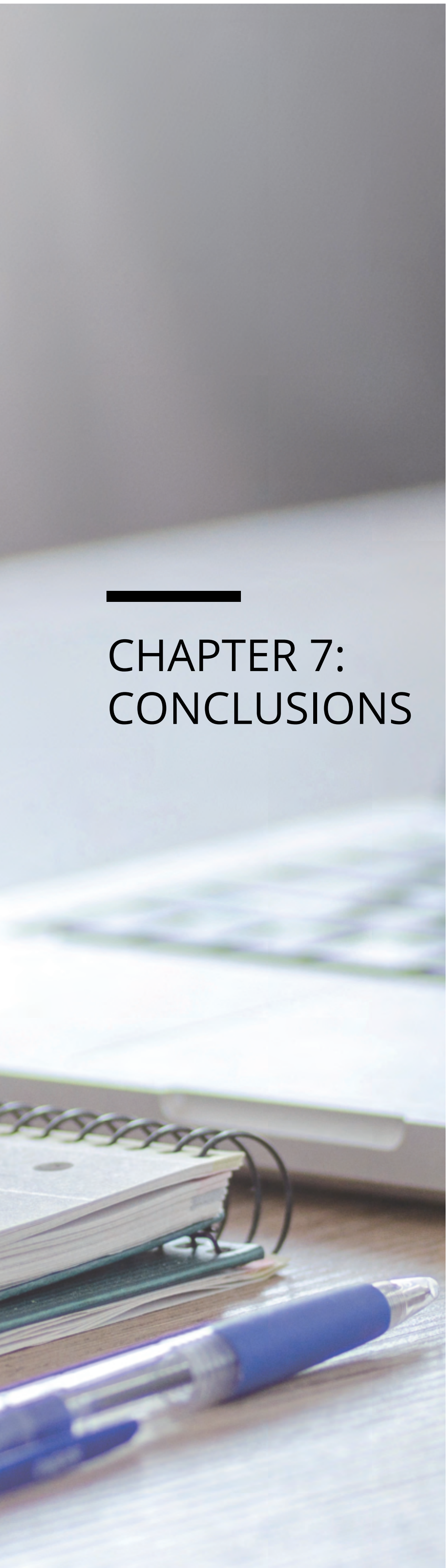
Recommendation 11: Promote battery recycling to the commercial sector

In December 2017, the HKSAR Government announced the Hong Kong Smart City Blueprint report. In the "Smart Environment" section of the report, the Government encouraged using smart technology for energy saving and in green building design. One excellent use for retired batteries is for building energy storage – not only can this extend the battery life cycle to benefit the environment, it can also help develop a green and smart community. It is recommended that the policy makers play a more active role in promoting battery recycling to the commercial sector and encouraging more demonstration projects for second life batteries.

Recommendation 12: Make the best use of the existing funding schemes to help the development of the battery recycling industry

The specific policy for vehicle Li-ion battery recycling shall be launched in order to support recycling companies attending battery recycling business. Technology for Li-ion battery recycling should be developed and provided to the interested parties to reuse the retired battery. To support the sustainable development of the recycling industry, the HKSAR Government announced in its 2014 Policy Address that HKD one billion has been earmarked to set up a Recycling Fund. The interested parties should make the best use of the Recycling Fund Scheme to help the development of the battery recycling industry.





CHAPTER 7: CONCLUSIONS

Better Government policies required to facilitate the adoption of EVs in Hong Kong

This report reviewed the EV adoption status in major cities around the world and the government policies of several major countries regarding promoting the adoption of EVs. Specific needs in Hong Kong were identified to help the city work towards the idea of green transportation through the use of EVs as both private cars and commercial vehicles. Compared with private electric vehicles, commercial EV adoption in Hong Kong still faces great challenges and more effort is required to promote EVs for commercial use. Aside from offering direct subsidies, more policies, e.g. financial incentives, should be adopted to encourage the private sector to participate in building a culture of EV adoption and use. On top of this, greater support for emerging EV technologies is also urgently required.

More efforts needed to promote EVs for commercial use

Commercial vehicles are the major source of roadside emissions in Hong Kong. Efforts to reduce these emissions will be much more effective if commercial vehicles were powered by electricity instead of internal combustion engines. This report's recommendations for promoting commercial EVs include:

1) Installing quick charging facilities with a minimum of 200kW which can charge a typical commercial EV battery within 30 minutes;

2) High-power charging stations should be located near highway entrances and exits. Charging stations should be built to ensure that heavy-duty commercial EVs can complete their entire journey on a highway, thus located these charging stations near highway entrances and exits is necessary;

3) Develop EVs for commercial use, as there are currently no approved models for medium-duty vehicles, heavy-duty vehicles or special-purpose vehicles like crane lorries, tankers, dump trucks, tractors, or refuse collection vehicles.

The development of EV charging in Hong Kong

Over the past few years, stakeholders in the EV charging industry have been more proactive about contributing to the expansion of the EV charging network to support the rapid growth of EV adoption in Hong Kong. However, there are still many challenges involved in catering to the possible future demands that will be placed on Hong Kong's EV charging infrastructure:

1) Business model concerns – There is little incentive for the development of sustainable charging service businesses (which offer paid charging services), since the majority of public charging services are currently offered for free. Therefore, incorporated owners are still hesitant to invest in or approve the installation of EV chargers.

2) Lack of a centralised data platform – A centralised data platform is critical to the sharing of EV charging data such as the real-time status of chargers. Such a platform will allow the various stakeholders to tailor their products and services to EV users more effectively, and for EV users to enjoy a more convenient charging experience. In addition, establishing a neutral industry association comprised of members from the various

stakeholders will help to drive the development of the industry and share a variety of engineering points of view with the Government.

3) Emerging charging technologies – Innovative EV charging technologies and solutions are emerging, and governments around the world are keen to adopt these technologies to benefit the public. In federal action announced by the US government, the government is creating an environment which will facilitate big data analytics to inspire new EV charging solutions. In the Netherlands, the Living Lab Smart Charging platform has been established. This is an open platform where companies, universities, local and regional governments and grid operators cooperate. EV charging technologies which hold great near-term promise include:

a) WEVC
b) Smart power distribution (also known as load management)
c) Mobile EV chargers
d) High-power charging
e) An interoperable EV charging network

Emerging EV technology

Emerging EV technologies include wireless charging, a dynamic EV charging network, V2H and V2G technologies, IoV and autonomous driving. All of these are new technologies for Hong Kong which will greatly benefit EV stakeholders and further promote EV adoption. However, stakeholders in these emerging technologies face a lot of adoption-related problems, including:

a) Little support for participating in emerging EV technology markets;
b) High investment in infrastructure;
c) No local venue to obtain the latest information, perform pilot tests and showcase achievements;
d) Regulation approval required for using emerging technologies on EVs;
e) Lack of availability of open data for “connected” vehicles;
f) 5G network is not yet ready;
g) Big data analytics capability is not yet ready.

Five key areas for EV adoption

Based on the interviews and desktop survey conducted with local stakeholders, this study identified five key areas of the EV industry infrastructure and ecosystem that need special attention and support in order to reduce barriers to the adoption of EVs.

These five areas are:

a) Government policy in facilitating EV adoption;
b) The set-up of EV charging infrastructure;
c) Emerging EV technologies;
d) Talent development for EV maintenance and support; and
e) The decommissioning of batteries and EVs

This study comprehensively looked at each of these five areas, examining them from the angle of overseas practices and initiatives, and from the perspective of stakeholders in the local environment. For each of these five key areas, the study provided a set of recommendations for key stakeholders including the policy makers, service providers, property management companies and property owners, as well as training institutions.

The Way Forward

This study has sought to identify additional strategic directions and initiatives which have the potential to further promote EV adoption in Hong Kong. However, the process of taking on board, fulfilling these recommendations and integrating them into the government’s policy infrastructure is outside the scope of this study, as executing these recommendations would necessarily demand further in-depth study and consultation with regard to strategic priorities and resource planning.

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