Sustainable Energy Association of Singapore

A case for sustainability:

Creating a Level Playing Field for Electric Vehicles in Singapore

A White Paper by the

Sustainable Energy Association of Singapore

26 July 2016

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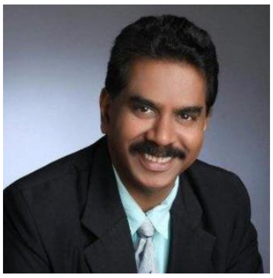
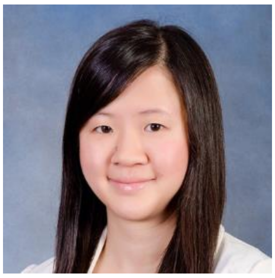
	**V. Anilan** Managing Director, Bus Hub Service Pte Ltd

	**Valerie Choy** Senior Consultant, DNV GL – Energy, DNV GL Singapore Pte Ltd
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Acknowledgements

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Table of Contents

Glossary

AAU	Assigned Amount Unit
ARF	Additional Registration Fee
BAU	Business as Usual
BCA	Building & Construction Authority
CAPEX	Capital Expenditure
CCS	Combined Charging System
CEVS	Carbon Emissions-based Vehicle Scheme
COE	Certificate of Entitlement
COP	Conference of the Parties
EDB	Singapore Economic Development Board
EV	Electrical Vehicle
GHG	Green House Gases
GVR	Green Vehicle Rebate
HDB	Housing and Development Board
ICEV	Internal Combustion Engine Vehicle
LTA	Land Transport Authority
NEA	National Environment Agency
OPEX	Operating Expenditure
PARF	Preferential Additional Registration Fee
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaic
SCDF	Singapore Civil Defence Force
WDA	Workforce Development Agency

1. Executive Summary

For any given vehicle population, displacing fossil fuel vehicles with electric vehicles (EVs) will improve the island's air quality, and reduce pollution related costs, while contributing towards Singapore's COP 21[1] commitments.

With the announcement during the Singapore parliament session on the 9th of May 2016 for the roll out of 2,000 charging stations, and the recent announcement to roll out all-electric taxi fleet to further decarbonise the transport sector, it is now pertinent to have the right charging infrastructure, standards and policies available for other adopters of electrical vehicles in Singapore to ensure a level playing field.

This white paper explores the following ten-point list and proposes policies and benefits of creating a level playing field for electric vehicles.

1. Charging Standards

With charging standards evolving, the standard must be defined clearly from the start with the view of adopting the latest technology to avoid legacy issues and to leapfrog adoption. Based on the most recent information at the writing of this white paper, Singapore will adopt the Type 2 AC and Combo 2 charging systems according to the IEC 61851 series and 62196 series as the national standard going forward[2] for new EV charging infrastructure[3] [4]. Since the DC charging standards follow the same standards family, this would allow the charging of EV in AC and DC mode with one compatible plug. This would enable easier adoption in the future when solar Photovoltaic (PV) based charging systems become more available.

2 Infrastructure

As the infrastructure standards differ widely for cars and buses. Infrastructure for cars must be accessible and scattered across the island to ensure vehicles are able to readily charge at different locations. For buses, the infrastructure should be logistically convenient. As buses already tend to have terminal and hubs, these are readily available sites for the development of the necessary infrastructure for buses to recharge during their downtime.

3. Infrastructure Operation and Maintenance

The Singapore government owns the public bus fleet, however, the construction, operation and maintenance of the charging stations does not have to be undertaken by the government. The option of tendering the charging facilities to private operators to reap the benefits through the open market results in low cost and high quality of service. A cost-benefit study with participation from both the government and industry can determine the additional requirements for power distribution infrastructure and examine mechanisms through which costs can be socialised among users.

4. Building Codes

Building codes such as the BCA Green Mark already take into account EV lots upon building completion but fail to promote easy installation of EV charging infrastructure post-building completion. To ensure a future-ready building infrastructure and the movement towards a SMART Nation, buildings codes should include the needs of EV charging for both expected current population and future expansion

[1] COP21 is the 2015 United Nations Climate Change Conference, which was held in Paris, France from the 30th of November 2015 to the 12th of December 2015.

[2] Singapore Economic Development Board. (30 June, 2016). *Singapore launches Nationwide Electric Vehicle Car-Sharing Programme*

[3] Appendix L – Charging Standards

[4] Land Transport Authority. (30 June, 2016). *JOINT NEWS RELEASE BY THE LAND TRANSPORT AUTHORITY (LTA) & EDB - ELECTRIC VEHICLES (EVS) IN EVERY HDB TOWN BY 2020*

of EV-ready car lots. Green Mark can evolve to promote this change and could allocate more points for EV-readiness.

5. Reduction in Carbon Emissions

As EVs emit no tail pipe exhaust, emissions would be centralised at power plants. Singapore's power plants use efficient combined cycle gas turbines, which have a lower carbon footprint per unit of energy than conventional fossil fuel based vehicle internal combustion engines[5]. Pressure for Singapore's power plants to remain competitive in the electricity market will ensure increasing and optimal efficiency of their systems. They will upgrade to meet operational and legislative requirements such as meeting very strict flue gas emission standards. An additional benefit of centralising emissions is a reduction in vehicle emissions on the roads, thus improving air quality for residents and visitors to Singapore. This will reduce carbon emissions from internal combustion engine vehicles, thus supporting our COP21 goals[6].

6. Green Vehicle Rebates

Green vehicle rebates should be optimised to fit the growing changes in electrical vehicles. To maximise the impact of the Carbon Emissions-based Vehicle Scheme (CEVS) in enticing would-be car buyers to purchase low emissions cars, the Preferential Additional Registration Fee (PARF) value of cars which received the CEVS rebate should be based on the Additional Registration Fee (ARF) value before the rebates, not after[7].

The green vehicle rebate scheme could be done away through an Operating Expenditure (OPEX) Scheme. This could be achieved by establishing a higher tariff for electricity dispensed by any EV charging outlet. This is easy for public and commercial charging stations, but can be tricky to impose on home charging stations, especially as many of these might also dispense zero-emissions solar electricity during the day. They would need a tamper-proof way of separately metering the grid electricity supplied through the charger. Another advantage of replacing CEVS with an OPEX-based scheme is that it eases traffic congestion by increasing the variable cost of driving versus using public transport. The existing cost structure of car ownership is too heavily weighted by fixed acquisition cost, which encourages people to use their cars even for trivial journeys, because variable costs (fuel and parking) are so low.

7. Reduced Noise Pollution & Improvements in Health

Levelling the playing field for electrical vehicles beyond cars would increase the adoption of electric heavy vehicles such as logistic fleets or buses. The vehicle road noise can be reduced in areas across Singapore which would increase the standard of living in the country. Lower urban pollution reduces health costs as well as the cost of maintaining and cleaning buildings.

8. Economic Benefits for Buses

To assist existing bus operating companies, the purchase of a new fleet of electric buses would make economic sense for both public and private bus operators, the latter benefitting from the shorter ROI to COE period[8].

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[5] This assumes the boundary for the calculations are Singapore's borders.
[6] Appendix N – Carbon Emissions
[7] Appendix E – Base PARF value calculation on ARF value before rebates to achieve full impact of CEVS shows a detailed calculation.
[8] Appendix I – Comparison of Buses

9. Awareness with Continual Education & Skills Future

With the increasing adoption of electrical vehicles in Singapore, the population should be educated and made aware of electrical vehicles. This could be achieved by training individuals under national skills programmes such as Skills Future or Workforce Development Agency (WDA) supported courses to enhance their knowledge in the operation and maintenance of EVs. As EVs operate on electricity, in the unfortunate event of a vehicle catching fire, the public and the Singapore Civil Defence Force (SCDF) should know how to handle electrical fires.

10. SMART Nation & Regional Hub

To keep Singapore at the forefront of technology and working towards a SMART nation, a level playing field for vehicles presents an opportunity for Singapore to set up a regional centre with full test facilities for batteries and charging infrastructure to ensure a consistent standard for electrical vehicles. This will help accelerate the deployment of electrical vehicles and there will be sufficient volume to ensure that the centre is economically viable with Singapore taking the lead in the region.

2. Introduction

At the Clean & Green Singapore 2015 launch on the 8th of November 2015, the Prime Minister Mr. Lee Hsien Loong said that "we will aim for a "Car-lite Singapore" by promoting and developing other modes of transport, making them convenient. We have to rely less on cars on the roads because we cannot keep on building roads – more roads for more cars. So we will provide more options for Singaporeans that are better than cars. Buses, more of course. Expanding the MRT network – that is happening everyday – but also other modes of transport for example, bicycling."

Singapore's Car-lite Transport vision factors the reduced presence of cars supported by an effective (i.e., extensive) and efficient (i.e., reliable) public transport system. This white paper proposes to further enhance these National objectives, around land use and urban mobility. The focus here is to identify key levers for a fair opportunity to de-carbonise part or all of the remaining vehicles (especially cars & buses) plying the streets of Singapore. This is especially pertinent following our commitment at the 2015 United Nations Climate Change Conference (COP21) to reduce the carbon intensity and footprint of Singapore, and our collective vision of a Clean & Green Singapore for a sustainable future. Therefore, Singapore must continue to look to new low (to zero) carbon emission technologies to help Singapore realise these goals.

There is no doubt that new infrastructure, services and policies will encourage the use of bicycles, skating/scooters and walking as key sustainable modes of urban mobility, as this is critical to solving the equation demanded by the Car-lite vision in a tropical climate. An upcoming big step will be the increased deployment of the fully electrified Mass Rapid Transport system to ensure mobility in Singapore is efficient and effective for its fast growing population and the need to travel across the island for social and business reasons.

To further support our efforts to reduce our transport sector's carbon foot print, the opportunity to decarbonise both the car and bus population in Singapore has begun to knock at our door. This can no doubt be partially achieved through fuel switching i.e., from liquid fuel to gas. But past experience suggests this is too riddled with deployment challenges to be effective. This could change with future efforts to convert all the town gas to methane, thus expanding access to gas from the reticulation system. However, the accelerated technological breakthroughs in energy storage science over the last 10 years with significant improvement projected to continue over the next 10-20 years both in terms of technology and manufacturing scale, has now created a big opportunity for electric (energy storage based) mobility of all sorts.

Electric cars and buses therefore become key levers that we can pull in our efforts to meet our commitments to COP21, by reducing or eliminating the use of the internal combustion engines on Singapore's roads. It is therefore important that current policies affecting the ownership and deployment of such vehicles are either tweaked, revamped or extended to ensure that these low carbon (zero emission) technologies operate under a policy regime that promotes a level playing field (versus the incumbents) for all modes of transportation. This is a minimum to ensure fair play in low carbon technologies' bid for deployment in Singapore's transport landscape.

A big step forward to reach the objective set out in COP21 was taken on the 9th May 2016 when transport Minister, Mr. Khaw Boon Wan announced in Parliament that Singapore is to set up 2,000 charging stations across the island[9].

[9] Straits Times. (9 May, 2016). *Parliament: Singapore to set up 2,000 electric vehicle charging points*.

This white paper highlights where the government can play an active role with policy instruments that would create this level playing field for cars and buses in particular. We have excluded motorcycles in this paper as we consider their impact on the carbon foot print is minimal.

3. Current Situation of EVs in the Transportation Sector

3.1. Fuel in Vehicles

In Singapore, petrol is by far the most commonly used fuel for vehicles, despite an older levy of S$0.44/L which was increased to S$0.64/L in Feb 2015[10].

Diesel adoption is low in Singapore as diesel engines are perceived to be noisy, smelly and known for black exhaust. They are also associated with the social stigma of goods vehicles such as trucks and vans, and taxis, which have diesel engines.

This legacy issue has suppressed demand for diesel-power passenger cars in Singapore. In the recent years, European manufacturers with new, advanced diesel technologies began introducing diesel models based on the developing EURO diesel standards.

The National Environment Agency of Singapore has announced from 1st January 2018, EURO VI standard will come into force for diesel vehicles in Singapore [11] [12].

For the year 2015, the breakdown of the type of fuel used for cars and buses are as follows:

Table 1 – Types of fuels which cars operate on in Singapore in 2015[13][14]

Car engine fuel type	Car population
Petrol	587,900
Diesel	5,976
Petrol-Electric	6,371
Petrol-Electric (Plug-In)	108
Petrol-CNG	1,932
CNG	0
Electric[15]	1
Diesel-Electric	23
Total	**602,311**

[10] Ministry of Finance. (23 February, 2015). *Singapore Budget 2015 - Measures for Businesses*.
[11] National Environment Agency. (30 December, 2014). *Singapore Will Usher in Euro VI Emission Standard for Diesel Vehicles from January 2018.*
[12] Appendix D – Private Cars
[13] These figures do not take into account taxis operating in Singapore, nor do they include EVs from LTA's EV test bed phase-1.
[14] Land Transport Authority. (21 March, 2016). *Publications & Research.*
[15] This figure does not take into account the 89 EVs which have been used as part of the EV Test Bed Phase 1. (Eco-Business, 2014)

Table 2 – Types of fuels which buses operate on in Singapore in 2015 [14]

Bus engine fuel type	Bus Population
Petrol	93
Diesel	17,629
Petrol-CNG	2
CNG	12
Diesel-Electric	4
Total	**17,740**

3.2. Carbon Emissions

Following Singapore's National Climate Change Secretariat (NCCS) business-as-usual (BAU) scenario, the transport sector will contribute 14.5% of greenhouse gas (GHG) emissions in Singapore in 2020. This makes the transport sector the second largest contributor of GHG emissions behind the industry sector. Emissions reduction in this key sector is therefore crucial to Singapore's commitment to reduce our GHG emissions per GDP dollar by 36% by 2030, compared to 2005 levels. [16]

The transportation sector is estimated to contribute 13% of emissions reduction through strategies such as achieving 70:30 modal split between public and private transport and the implementation of a Carbon Emissions-based Vehicle Scheme (CEVS) to encourage the purchase of low carbon emissions cars. The CEVS, introduced in 2013, offers tiered rebates and mandates surcharges for low and high carbon emission vehicles respectively. The CEVS replaces the Green Vehicle Rebate (GVR) scheme, which ran for nine years from January 2004 to December 2012, and offers greater rebates for low emissions vehicles compared to its predecessor.[17] [18]

3.3. Charging Infrastructure and Standards

EVs have a different operating energy and charging medium from the internal combustion engine vehicles. This would require prudent planning to ensure adoption proceeds smoothly. This involves looking at the charging standards and infrastructure for both cars and buses which vary due to the nature of service provided by the vehicle type.

3.3.1. Types of charging standards

Currently, there are two main standards, one for American and Japanese vehicles, the other for European vehicles. [9] Having the right charging infrastructure in place is essential for the adoption of EVs in Singapore.

Multiple plug designs and charging modes have been developed by various EV manufacturers. To ensure EV drivers can conveniently charge their cars, requires interoperability and standardisation for the various charging modes and plug types. [19]

[16] National Climate Change Secretariat. (10 February, 2016). *Singapore's Emissions Profile*
[17] Appendix H – Carbon Emissions, has calculations relating to the difference from the well to wheel and grid to wheel emissions.
[18] Land Transport Authority. (28 November, 2012). *Rebates for Low Carbon Emissions Cars from 1 January 2013*
[19] Appendix L – Charging Standards, has more information on the different standards globally.

3.3.2.Charging infrastructure for cars

It is of paramount importance to clearly define the charging infrastructure standard from the start to ensure a smooth adoption.

Singapore's first charging service provider (CSP), Robert Bosch (SEA) Pte Ltd, supports the EV Test-bed by designing, building and maintaining more than 60 outdoor normal charging stations and 3 outdoor fast chargers. Indoor charging stations are managed by its sub-contractor Greenlots.

Some key challenges relating to the charging infrastructure may impede consumers' transition to EVs. There is no standardised public charging infrastructure for both public convenience and reliability. Although the Technical Reference for EVs Charging Systems under the Singapore Standards serves as the best practice guide for CSPs, rapidly changing technologies (especially DC charging technologies) may cause the public to hesitate in converting to electric mobility because of uncertainty over vehicle compatibility in the future.

As the majority of Singaporeans live in high-rise buildings with limited parking spaces, competition for charging spots will result. This calls for the centralised management of a network of charging service areas which are both accessible and adequate in numbers. Establishing a common charging standard will further ensure interoperability for the stations, thereby boosting confidence in E-mobility.

Without a reliable and robust charging infrastructure in place, "range anxiety" will prevail among the public despite the average driving range of an EV greatly exceeding the average daily driving distance in Singapore. A typical EV's range is 120-160 km per charge while the average car's daily driving distance in Singapore is 46 to 50 km. Furthermore, smart technologies that enable EVs to locate and even book the closest available charging station, should mitigate range anxiety issues.

Although normal domestic slow charging chargers require 8 hours to go from empty to full capacity, high-capacity fast chargers can achieve shorter charging durations e.g. 30 mins for 80% capacity. Coupled with opportunistic charging when the vehicle is parked at different locations with EV charging stations, the need for 8-hour charging sessions can be dramatically reduced or avoided altogether. Thus there is a role for public education on managing EVs.

With the announcement in Singapore parliament on the 9th of May 2016 for the roll out of 2,000 charging stations, EV range anxiety within Singapore would be further alleviated as adopters would benefit from readily available charging infrastructure coupled with the fast chargers. On 30th June 2016[20], following the announcement on 9th May 2016 in parliament, of the 2,000 charging stations deployed, 20% will be made available for public use and the remaining 80% for the EV car sharing scheme.

On 30th June 2016[20], it also was announced by EDB that Singapore will adopt Type 2 AC and Combo 2 charging systems according to the IEC 61851 series and 62196 series (which allows slightly faster charging than Type 1) as a national standard going forward[21].

[20] Singapore Economic Development Board. (30 June, 2016). *Singapore launches Nationwide Electric Vehicle Car-Sharing Programme*

[21] Appendix L – Charging Standards, has an image of the charging standard

Another major concern is battery life and performance. The battery is the most expensive component of an EV and whether the warranty on the battery can be extended for 10 years still remains to be determined. Albeit there is second life on these batteries which can used to supplement solar-storage hybrid options, car manufacturers will need to develop their own business models and innovative solutions to address this concern for the consumer.

3.3.2.1. Carparks and future ready infrastructure

Currently, Housing and Development Board's (HDB) car parks and town councils have sufficient power to operate standard systems, which are the lighting and/or sprinkler system as per guidelines. However, their electricity supply is insufficient for more than one or two type 1 charging stations.

Here is an example to illustrate this point. A carpark with 200 fluorescent tubes of 60W each requires an electric supply capacity of 12kW. The carpark's electricity supply will be sized according to this demand and will not deviate from the maximum expected load. A type-1 slow charging station with one plug requires 3.3kW which is equal to 27.5% of the total car park's power supply. Two type-1 slow charging stations with two plugs each could double the car park's electricity demand if all plugs are used concurrently. Hence the electricity supply has to come from the nearest external sub-station instead of the car park's switch room. Additional planning, works and budget are required to retrofit charging stations if this load was not already provided for in the original carpark design.

Existing building codes for car parks during the development phase from the LTA do not consider the needs of future EV charging infrastructure that might be installed after the building has been constructed. [22]

We therefore recommend the following for a future ready infrastructure for EVs in Singapore.

- Petrol stations are already well distributed across Singapore. They could include charging stations, making use of their current location and if space availability and safety considerations permits such installation.
- Public common charging stations should be made available for individuals to charge their EVs.
- Develop innovative payment solutions to ensure individuals pay for the energy consumed and to ensure that vehicles make way for others upon being fully charged.
- BCA Green Mark standard should take into account the possibility of expansion of EV charging stations within car parks. This would ensure that car parks will be future ready.

[22] Land Transport Authority. (2011). *Code of Practice - Vehicle Parking Provision in Development Proposals.*

3.4. Government Initiatives in E-Mobility

LTA and EDB launched the EV Test Bed Phase 1 in 2011 and from this, 3 key findings were observed[23]:

1. Purchase price was the greatest inhibiting factor, with respondents indicating that they would consider EVs only if they cost approximately the same as ICEVs.
2. Concern over range was the next major issue raised, with over 50% indicating insufficient range as a problem, even though only 4% of those surveyed travelled more than 80km a day.
3. Respondents were also worried about insufficient availability of personal and public charging infrastructure.

From the key findings from the first test-bed on electric mobility done, the following points reinforce this white paper:

1. The use of EVs is technically feasible in Singapore based on driving and charging data. Average EV driving distance is 46km which is close to the national average of 50km.

2. The impact of EV charging is not significant to electricity generation. If all private cars were to convert to EV, the demand increase of the grid would be 4.8%. However, the impact to the grid could be significant with the deployment of fast chargers depending on that particular section's infrastructure[24].

3. EVs are currently not deemed economically feasible as the OMV is three times higher than a comparable internal combustion engine vehicle (ICEV). Therefore, a benefit-based tax structure that levels the playing would play an important role.

In December 2014, LTA and EDB announced the Electric Vehicle Car-Sharing Programme. This 2nd phase plans to trial an EV car sharing programme which will see the introduction of up to 1,000 EVs and the supporting charging infrastructure. The following strategy has been proposed.

Figure 1: LTA's EV Test Bed Phase 2 Plans

It has also highlighted the importance of advancing the battery technology to improve range, performance and battery life while reducing the cost of the battery at the same time. LTA has also indicated the necessity of harmonising charging standards and infrastructural management. Moreover, it is looking into innovative business models such as battery leasing and car-sharing.

LTA has also awarded an e-mobility roadmap study to be done by the Energy Research Institute @ Nanyang Technological University (ERI@N) amongst others, to analyse the emission reduction potential of EVs in Singapore. This shows that the Singapore government is keen on deeply analysing the feasibility of EVs in Singapore and addressing the issues identified from the test beds.

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[23] Land Transport Authority of Singapore. (8 December, 2014). *Joint News Release by the Land Transport Authority & EDB on EV Phase 2 – Share an Electric Car.*

[24] Please refer to section 3.3.2.1 - Carparks and future ready infrastructure

4. The Case for Electric Vehicles

EVs have the following significant advantages over gasoline or diesel-powered engines:

- Reduced CO_2 emissions, especially if renewable energy sources such as solar PV are used for charging,
- Lower operating cost for vehicle owners as there are fewer moving parts,
- Improved air quality due to no tail pipe emissions,
- Reduction of noise on roads as EVs are quieter than ICEVs.

4.1. Emission Comparison – Internal Combustion Engine Vs Electric Motors

The emissions from transportation sector are one of the largest contributors to urban pollution. Even with the technological improvements of engines and emission standards for conventional fossil fuel engines, tailpipe emissions are constantly under regulatory watch.

Vehicle companies have been able to reduce the impact of each car on the road, by the use of more refined fuels as well as more efficient engine and vehicle technology. Advances in catalytic converters and particulate matter filters which are part of the tailpipe assembly have also played their part in mitigating some of the pollution. However, constant vigilance and due diligence in testing is still required to ensure that vehicles match their rated road emissions and fuel efficiency[25].

Rapid advances in battery technology have enabled many automobile companies to introduce EVs, which are rapidly closing the gap with conventional combustion engine capabilities. Therefore, EV adoption is being strongly promoted, especially by the automobile technology leaders.

EVs are not emissions-free, despite the complete lack of tailpipe emissions that make EVs an attractive answer to the transportation emission problem. As long as their electricity is not from a renewable source; EVs cannot be emissions-free. A power plant-to-wheel study needs to assess the emissions from fossil fuel power plants when they generate the electricity consumed by EVs. Hence, a representative figure for an EV's emissions should account for emissions at the power plant as well as transmission and distribution losses in the grid.

4.1.1. Basis of comparison

To compare the total emissions from EVs and internal combustion engine vehicles ICEVs, a similar approach to a life cycle assessment (LCA) will be used. In context of the fuel or energy source of EV, instead of a well-to-wheel assessment, a power plant to wheel assessment is deemed more appropriate for Singapore's context.

The boundary defined for this comparison is Singapore itself, and excludes all associated emissions beyond the borders. For ICEVs, the emissions from the refinery attributable to the production of gasoline and the operation emissions are considered. The emissions related to transportation and storage of the gasoline from the refinery to the petrol pumps are assumed to be insignificant for this analysis. The emissions related to exploration of crude and its transportation to Singapore refineries are not considered.

For EVs, the emissions related to the generation and transmission of electricity from power station to wheel are considered. The fossil fuels used in the power plants are imported to Singapore and hence the production and transportation related emissions of the fuel are beyond the scope of this analysis.

[25] Cars in Singapore are required by law to undergo a road worthiness inspection process to ensure that they are environmentally-friendly and do not become safety hazards to others on the roads. The inspection frequency ranges from 6 months to biennially. (STA Inspection Pte Ltd, 2012)

The grid emission factor of Singapore is used to determine the emissions related to electricity generation in Singapore. The grid losses and the charging efficiency of the EV battery are incorporated into the calculation as well.

Following a comparison of fuel economy of average mid-sized passenger vehicles of the ICEVs and EVs, the following emission estimates for each type of vehicle were derived.

4.1.2. Emissions of an internal combustion engine vehicle

During operation, an ICEV emits around 2.35 kg CO_2/litre of gasoline combusted [26]. For an average mid-sized passenger vehicle, the fuel consumption is about 0.067 litres per km which translates to 157 g CO_2/km of emissions from the tailpipe of an ICEV [27]

Apart from tailpipe emissions, we must account for the emissions from the production of the fuel, to understand the overall impact of the ICEV. The emissions for refining gasoline from crude were estimated at 0.23 kg CO_2/litre of gasoline produced [28]. Calculating per km emissions by using the fuel consumption values, the emission contribution from refining comes to 15.41 g CO_2/km. Emissions associated with transportation of fuel from refinery gates to various parts of Singapore are considered negligible and hence not used in this analysis. Summing up, the total emissions per km are 173 gCO_2/km.

4.1.3. Emissions of an electric vehicle

The average energy efficiency of EVs sold in 2015 in the United States was determined as 0.32kWh/mile by U.S. Alternative Fuel Centre [29]. This efficiency is estimated while considering battery discharge losses (16%) and regenerative gains made during the braking of the EV (17%) [30].

Accounting for the charging losses of 16%, an average EV draws about 0.37kWh of energy from the grid for every mile. Including the transmission losses of 2% to this calculation, the required power generation for an EV to cover of distance comes to 0.38kWh/mile, or 0.24kWh/km.

Singapore's latest grid emission factor is for the year 2015, as published by the Energy Market Authority, and stands at 0.422 kg CO_2/kWh [31] [32]. Hence for every km an EV operates, its equivalent emissions are 101.28 g CO_2/km, which is about 41% lower than an equivalent conventional vehicle running on gasoline.

[26] Environmental Protection Agency. (7 May, 2010).
[27] U.S. Energy Information Administration. (22 July, 2014). *Fuel economy and average vehicle cost vary significantly across vehicle types.*
[28] European Commission JRC Technical Reports. (April, 2014).
[29] U.S. Department of Energy. (11 March, 2016). *Alternative Fuels Data Center: Hybrid and Plug-In Electric Vehicle Emissions Data Sources and Assumptions*.
[30] U.S. Department of Energy. (2015). *Where the Energy Goes: Electric Cars*.
[31] Energy Market Authority of Singapore. (18 May, 2016). *Electricity Grid Emissions Factors and Upstream Fugitive Methane Emission Factor.*
[32] The grid emission factor value is the combined emission factor which is the average of the operating margin (0.4313 kg CO_2/kWh) and the build margin (0.4126 kg CO_2/kWh).

4.2. Air Quality

4.2.1. Public health

Combustion of fossil fuels in ICEVs or power plants not only produces GHGs but also emits other harmful air pollutants, which have an immediate impact on public health. In 2010, China reported 1.23 million premature deaths related to $PM_{2.5}$, one of the pollutants released during fuel combustion in vehicle engines. This amounts to 9.7 – 13.2% of China's GDP in damage equivalent. [33] Pollution due to vehicles is both lethal to humans and detrimental to the economy. Hence, it is vital that Singapore strictly monitors and controls its air quality.

Harmful tailpipe emissions of petrol and diesel ICEVs are mainly particulate matters ($PM_{2.5}$ & PM_{10}), Nitrogen Oxides (NO_x), Hydrocarbons, Carbon Monoxide (CO) and Sulphur Dioxide (SO_2). The health implications of exposure to these pollutants and the guidelines to exposure limits are summarised in Appendix J – Regulations & Measures for Petrol and Diesel Vehicle Emissions .

4.2.2. EVs for better air quality in the city

EVs shift emissions from public spaces to centralised locations such as power plants. This is because EVs are a non-emitting mobile source which are able to move better through areas of high population densities such as residential and CBD areas without impacting the local air quality.

With emission sources centralised at the stationary power plants in industrial areas far from the general public, the overall air quality across the city would be improved for three main reasons. First, the distance buffer between the industrial and residential zones helps to minimise the health impact. Second, power plants face stringent emission standards, thus ensuring emissions are kept to a minimum. Lastly, Singapore's power plants burn natural gas, which is the cleanest fossil fuel.

Besides reduced health impact, cleaner urban air reduces the cost of keeping buildings clean.

Therefore, EVs would be a better option to enhance the air quality in general with current and improving regulations on power generating facilities. Furthermore, rapid improvements in EV efficiency will reduce electricity consumption, which translates to progressively lower emissions at the stationary fossil fuel power generation sources.

4.3. Business Opportunity for Bus Operators

On 17 March 2016, London's Transport Authority, Transport for London (TfL), launched its fully electric double decker bus fleet. It delivers an operating range of 309km on a single charge, with the charging process taking 4 hours. [34]

In Singapore, a conservative measure of a typical long distance route is approximately 40.2km. An electric bus could run close to 8 rounds of service on a single charge. The BYD-designed[35] buses deliver 345 kWh of energy and come with an industry benchmark warranty of 12-years (the longest warranty available). With fully functional infrastructure for off-peak slow charging, this could be the perfect substitute for Singapore's diesel-fuelled buses.

[33] The New Climate Economy. (2015). *The New Climate Economy.*
[34] Henderson, E. (17 March, 2016). *World's first electric double-decker bus launches in London*.
[35] BYD Auto Co., Ltd. is a Chinese automobile manufacturer.

4.3.1. Financial and comparative analysis of diesel-powered buses and electric buses

A comparative analysis of diesel-powered bus vs. electric bus will demonstrate the operational cost reduction opportunity in switching from the currently dominant diesel powered buses to electric buses. This would require additional funding to support the growth and development of other sectors of the bus operators.

Based on actual numbers provided by bus operators[36], the capital expenditure (CAPEX) for an electric bus is up to SGD$232,500 higher than that of a diesel bus. However, this CAPEX is more than compensated by the lower operational expenditure (OPEX) of an electric bus. Based on driving 300 km per day, the OPEX savings of the electric bus stands at SGD$ 51,983 per year[37]. This translates to a return on investment (ROI) of 4.2 to 4.5 years for replacing a diesel bus with an electric bus.

The ROI is generally shorter when comparing electric buses with public omnibuses than with private coaches. Nevertheless, the ROI is less than half the Certificate of Entitlement (COE) period[38]. Therefore, the purchase of a new fleet of electric buses would make economic sense for both public and private bus operators, the latter benefitting from the shorter ROI to COE ratio.

4.3.2. Charging infrastructure for buses

Replacing Singapore's diesel buses with electric buses would require sizeable investment in necessary infrastructure due to the unconventional way of fuelling an EV, especially buses, due to the nature of operations.

Existing infrastructure, including bus interchanges, terminals, depots and bus parks would have to be retrofitted with charging stations. This needs to be supported by a network of charging stations with a blend of fast charging (fringe of CBD) and slow charging (outskirts) stations located in bus parks.

Existing bus parks can be used, but space for individual charging stations need to be carved out. This would take a massive effort of restructuring the current fuelling stations and bus parking facilities.

With the advancement of battery and charging technologies, the electric buses only need to be opportunistically-charged for 10-15 minutes at a time during the day. This would reduce the ratio of chargers to buses; hence the cost of infrastructure will not be excessive. Opportunistic-charging extends range by 20-30km per quick charge, while a full charge takes about an hour and suffices for 140km.

Low cost slow-charging overnight coupled with opportunistic-charging during operational hours while the drivers change shifts or while passengers alight at the bus terminal, are sufficient for most bus and feeder routes in Singapore.

[36] Appendix I – Comparison of Buses tables 9 & 10 for estimate calculation based on actual numbers provided by bus operators

[37] Appendix I - Comparison of Buses tables 11 & 12 on Return on Investment

[38] All Excursion Buses, Private Buses and Private Hire Buses require a Category C or E ("open" for any type of vehicle) COE to be registered. School Buses are exempted from COE. However, no new School Bus licences are available, and must be purchased from the resale market. Existing School Bus owners are allowed to register a replacement bus with the exemption of COE. (Land Transport Authority, 2016)

While power distribution infrastructure in the outskirts of the city is expected to cope well with the surge in load at night due to a corresponding reduction in commercial and industrial load at that time, power distribution infrastructure closer to the city centre is expected to be stressed with the additional load on the system brought about by fast charging electric buses during the day. The charging can be managed by a fleet management system and scheduling for charging can thus be optimised for the different times of the day and night. Night time charging improves the average load factor on power plants, giving them a better return on assets.

5. Levelling the Playing Field - Recommendations

Based on the points which have been discussed and mentioned earlier, here are some of the recommendations in order to create a level playing field for e-mobility in Singapore.

5.1. Review CEVS to Create a Level Playing Field for EVs

5.1.1. Introduce more incentive bandings to further differentiate vehicles on the lower end of carbon emissions

EVs and PHEVs face disadvantages because of formulae used by LTA to calculate Carbon Emission-Based Vehicle Scheme (CEVS) rebates and road tax. This makes the price of EVs and PHEVs much higher than petrol vehicles. Although grid emissions are included in EV emission calculations, no such “supply / production chain” factor is applied to other Fuel Types. As a result, certain PHEV models are disadvantaged when qualifying for CEVS rebates. There is no formula specifically for EVs and PHEVs in LTA’s public domain.

A market perception survey conducted during Phase 1 of the EV test bed, which spanned from 2011 to 2013, revealed that the purchase price of an EV was a big inhibiting factor and purchasers would only consider EVs if they cost approximately the same as ICEVs [23]. However, due to relative technology immaturity, EVs are still more expensive than ICEVs today. The high cost is primarily due to the battery cost, which is coming down drastically each year. The CEVS, which provides rebates on the additional registration fee (ARF) for purchase of low carbon emissions vehicles, is the most promising mechanism for reducing the price of EVs.

To further encourage the purchase of low carbon emissions vehicles, the CEVS was revised in June 2015 to provide bigger rebates overall for low carbon emissions vehicles and increase the differentiation between varying levels of carbon emissions from the tail-pipe (measured in g CO_2/km).

The table below shows the revisions made:

Table 3 - CEVS Rebate for different vehicle categories revised from July 2015 [39]

Band	Existing CEVS (Till 30 Jun 2015)			Revised CEVS (From 1 Jul 2015)			Rebates/ Surcharges
	Carbon Emission (CO_2 g/km)	Cars	Taxis	Carbon Emission (CO_2 g/km)	Cars	Taxis	
A1	Up to 100	$20,000	$30,000	Up to 95	$30,000	$45,000	Rebates
A2	101-120	0	$22,500	96-105	$15,000	$22,500	
A3	121-140	$10,000	$15,000	106-120	$10,000	$15,000	
A4	141-160	$5,000	$7,500	121-135	$5,000	$7,500	
B	161-210	0	0	136-185	0	0	
C1	211-230	$5,000	$7,500	186-200	$5,000	$7,500	Surcharges
C2	231-250	$10,000	$15,000	201-215	$10,000	$15,000	
C3	251-270	$15,000	$22,500	216-230	$15,000	$22,500	
C4	Above 270	$20,000	$30,000	Above 230	$30,000	$45,000	

Although the bandings were adjusted to favour cars with lower carbon emissions (e.g. rebates for Band A1 increased from $20,000 to $30,000 for private cars with a corresponding decrease in qualifying carbon emissions limit for the Band from up to 100 g CO_2/km to up to 95 g CO_2/km), there is greater room to further differentiate rebates for cars with carbon emissions between 0 – 95 g CO_2/km in future reviews of the CEVS. For example, in France, rebates are differentiated among electric and hybrid cars that emit 20 g CO_2/km or less, 20 – 60 g CO_2/km and 61 – 110 g CO_2/km [40].

EVs have no tail pipe emissions. However, there are emissions produced from the generation of the electricity that EVs consume. Emissions resulting from the use an EV can be calculated by multiplying the electricity consumption of an EV with Singapore's combined grid emission factor. Using this calculation method, the emissions from a Nissan Leaf in Singapore is 62 g CO_2/km – significantly lower than the upper limit of 95 g CO_2/km in Band A1 [41].

Since EVs are the lowest carbon emissions among car models in the market, a level playing field in the CEVS can only be created by granting a higher incentive to EVs than to higher-emitting hybrid car models. The emissions of EVs are expected to fall further in the coming years as Singapore continues to expand the use of natural gas and renewables for electricity generation – justifying the need for more bandings in the lowest emissions end of the CEVS.[42]

[39] Land Transport Authority. (23 February, 2015). *Revised Carbon Emissions-Based Vehicle Scheme (CEVS) from 1 July 2015*.
[40] European Automobile Manufacturers Association. (2015). *Overview of Purchase and Tax Incentives for Electric Vehicles in the EU in 2015*
[41] Nissan. (1 May, 2016). *Nissan Leaf.*
[42] Appendix O – Base PARF value calculation on ARF value before rebates to achieve full impact of CEVS has a more detailed calculation.

5.1.2. Consider scrapping the CAPEX-based CEVS and replacing it with OPEX-based schemes

The CEVS aims to differentiate vehicles based on the CO_2 emissions per kilometre. But it does this quite poorly, since it cannot distinguish in advance between a vehicle that is driven primarily in stop-and-go CBD traffic (such as a delivery vehicle) and one that undertakes uninterrupted highway journeys (such as regular commutes across the island).

This inherent flaw becomes even more apparent when trying to compare CO_2/km between:

- A pure petrol or diesel vehicle
- A pure EV, charged by an uncertain mix of grid electricity and solar electricity, e.g. from the car owner's rooftop PV system
- A petrol / electric hybrid, with the battery charged by an uncertain mix of the fuel engine, grid electricity and solar electricity.
- A plug-in EV with petrol range extender.

Since Singapore tightly restricts the opportunity of buying fuel across the border in Malaysia, it can precisely capture and tax each vehicle's CO_2 emissions according to the quantity of fuel and grid electricity purchased, regardless of the fuel/electricity mix. We know the CO_2 emissions from burning a litre of petrol or diesel, and we know the grid emissions factor per kWh generated by our power plants.

While imposing a carbon surcharge on fuel is easy enough, doing the same on grid electricity is problematic. On one hand, the environmental impact of CO_2 emissions is the same, whether a power plant generates electricity for an EV or to power an office or factory. On the other hand, Singapore can ill afford to unilaterally impose significant carbon taxes in the absence of a global agreement, or its industrial competitiveness will suffer.

The question is how to selectively tax grid emissions on electricity used for private transport, without penalising other forms of electricity consumption.

One way is to establish a higher tariff for electricity dispensed by any EV charging outlet. This is easy for public and commercial charging stations, but can be tricky to impose on home charging stations, especially as many of these might also dispense zero-emissions solar electricity during the day. They would need a tamper-proof way of separately metering the grid electricity supplied through the charger.

Another advantage of replacing CEVS with an OPEX-based scheme is that it eases traffic congestion by increasing the variable cost of driving versus using public transport. The existing cost structure of car ownership is too heavily weighted by fixed acquisition cost, which encourages people to use their cars even for trivial journeys, because variable costs (fuel and parking) are so low.

5.2. Selection of One Charging Standard

In order to increase the usage of EVs, standardisation of the charging plug standard is of utmost importance. This is especially so with the recent announcement for the installation of 2,000 charging stations across Singapore.

There are 2 main IEC[43] charging standards:

- IEC type 1 implementation comprising single-phase AC charging (SAE J1772), and its variant Combined Charging System 1 (CCS1) which supports both type 1 AC charging (SAE J1772) and DC fast charging.
- IEC type 2 implementation comprising single-phase or three-phase AC charging, and its variant Combined Charging System 2 (CCS2) which supports both type 2 AC charging and DC fast charging.

The latest information presented on 30th June 2016 has placed the IEC 61851 and 62196 type 2 series as the national standard going forward. This would then allow EVs to charge in AC and DC mode with one compatible plug and would allow easier adoption in the future for solar Photovoltaic charging systems.

Further considerations when selecting the standard:

- Existing test-bed infrastructure was invested with considerable public and private funding. Changing to IEC type 2 would make the infrastructure obsolete and strand existing test-bed participants in the long term.
- Strong momentum in the adoption of EVs charging stations due to the BCA Green Mark Scheme[44] should not be underestimated. Many new buildings were completed recently and will complete in the near future in designated growth regions in the Central Business District, Jurong Lake District and the Paya Lebar area. Many such Green Mark buildings have already invested in or planned to invest in multiple type 1 AC charging stations (SAE J1772).
- A committee should be set up to ensure that the right standards are in place and are always developing. The Standards Council under SPRING Singapore can undertake this role to ensure that standards for EVs would be at the highest level.

It should also be noted that the charging infrastructure not only serves to supply electrons to the vehicle (and potentially in the future electrons back to the grid[45]) but also enables new business models for the retail or commercial sector. Therefore, having a standard multi service interoperable IT backbone will facilitate new services from retailers for consumers, fitting Singapore's vision of a Smart Nation. This would also facilitate a common cyber security architecture that can be easily rolled out nationwide.

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[43] IEC refers to the International Electrotechnical Commission which maintains the IEC 62196, which is the international standard for the electrical connectors and charging modes for electric vehicles.

[44] At the writing of this white paper, Green Mark Version 4.1 has the provision of electric vehicle charging stations within the development. The extent of this coverage is the minimum of 1 EV charging station for every 100 carpark lots capped at a maximum of 5. (Building Code Authority Singapore, 2012)

[45] Please see Appendix O – Vehicle to Grid Technology for more detailed information

5.3. Future Proofing New and Existing Buildings

HDBs and Town Councils need to provide a policy framework to enable private investments in EV charging infrastructure. To handle an increasing number of EVs in Singapore, the Town Council needs to prepare for this increase in existing carparks and HDB needs to take the increase into account when planning new carparks. It is not possible to forecast an exact figure, but the contingency planning should be in place. With the policies and processes in place to make private infrastructure easy, the business model could then be structured after that. For example, it would be possible then for HDB and Town Councils to not actually invest in the infrastructure, but they would be able to attract the private sector to run and operate the infrastructure.

The current BCA rules on carparks are restrictive and they need to streamline ongoing development in technologies. To ease the process of installing EV charging stations, some measures should be taken in existing and new carparks. For new buildings that are not yet constructed, BCA could mandate charging station parking lots and space for charging stations, as they do for handicap lots.

These lots should take into account the distance to the nearest switch room and the power available in that switch room. The cable containment from switch room to the CS parking lot should be built, even though it will be empty as long as there are no CSs installed. In the switch room, the charging station should have its own power meter to monitor the energy consumption. This would allow easier rolling out of new lots when required.

For existing buildings, the Green Mark point scheme has worked well so far for the adoption of EV charging lots in car parks. To accelerate the installation of CSs, existing buildings should be incentivised to plan ahead for a possible CS installation. Such a plan should state which parking lots will be used and which switch room the power will come from. The plan should consider the space needed for a CS as well as the standards and regulations regarding the installation space and try to minimise the cost of trunking from the switch room to the parking lot. Through this process, the Green Mark scheme could allocate more points towards enabling the retrofit of EV infrastructure. This would motivate building owners who want to achieve the required Green Mark ranking.

5.4. Setting up Regional Centre for Electric Vehicle Testing and Inspection

An opportunity to further establish Singapore as a Smart Nation and take advantage of the electrification of buses and cars is to establish a regional testing centre with full test facilities for battery and charging infrastructure that would ensure that all vehicles are tested by one common standard and process. This will help accelerate the deployment of EVs, while growing regional demand will ensure the centre is economically viable.

5.5. Investment in Electric Bus Fleet and Supporting Infrastructure

Although the government owns the public bus fleet entirely, it does not have to undertake the construction and operation of the charging stations itself. It can tender the charging facilities to private operators, to reap the benefits such as low cost and high quality of service of market competition. The government should also lead a cost-benefit study with participation from the industry to determine the additional requirements for power distribution infrastructure and examine mechanisms through which such costs can be socialised among users. The study could be carried out as a test bed whereby data of key matrices could be collected and analysed to ensure future adoption.

6. Skills and Training

While car manufacturers are ultimately responsible for training qualified personnel to service the EVs that they market, the government needs to play a central role in re-skilling the current workforce.

The Economic Development Board and WDA have embarked on skills and training initiatives to boost training and development of other “new” industries such as sustainable energy. The budget 2015 also announced subsidies for Singaporeans to upgrade their work skills as part of a new movement called Skills Future. This provides the opportunity for industry professionals to upgrade their skills and widen them for relevance to e-mobility. As Singapore undertakes R&D and feasibility studies on electro mobility, it must also consider skills and training to ensure a holistic development of the industry.

The Sustainable Energy Association of Singapore conducts certified courses under the Energy Conservation Act for energy managers, and solar PV design, installation, and maintenance courses which are relevant given the growth in solar PV in Singapore. To date, SEAS has trained 7,000 students since 2008 in the varying areas of sustainable energy.

With growth in sustainable mobility, the association can work together with industry experts to develop proper certified courses to train mechanics. Technical training institutes in Singapore like the Institute of Education and the polytechnics in Singapore could also launch programmes to cultivate a pool of qualified professionals.

7. Conclusion

There are sufficient areas of improvement to facilitate the decarbonisation of the transport sector and support the Smart Nation vision that complement the national “Car-lite” programme. It is inconceivable to imagine a Smart Nation without electric or autonomous vehicles (cars and buses). Singapore can afford to pursue some “big-hairy-audacious-goals”, BHAG, for example a target of greater than 75% electric cars and buses, and setting up a regional testing and inspection centre for electric mobility solutions of all sorts. These will yield economic, social and environmental benefits for Singapore in the long run.

Singapore, with an extensive charging infrastructure and high adoption of EVs across the different vehicle types would then be an ideal location for automotive companies to test bed their future technologies and products.

Appendix A – Singapore Policy for the private transport sector

Items	Direction	Current	Plan
Ownership	Control ownership number and discourage ownership	• COE (Vehicle Quota System) • Various Taxes & Fees	• Stabilize COE based on vehicle growth figure • Periodical review on ownership rules and taxes
On-road rules	Discourage road usage for private vehicles	• ERP • Car-free zones	• ERP utilizing GNSS • More ERP gantries • ERP price adjustment • More car-free zones
Alternative/ Cleaner Technology	Promote cleaner and fuel efficient vehicles	• Fuel Economy Labelling • CEVS based incentive/ surcharge	• Periodical review on CEVS • Enforce higher emission standard
New Technology & Program Exploration	Promote R&D to test on advanced technology for purpose of cleaner and more efficient	Electric vehicle pilot project	• EV car-sharing pilot • Driverless car • Hydrogen vehicles

Figure 2 – The policy for the automotive sector generally discourages private vehicle use and ownership while promoting advanced technology. Source: Frost and Sullivan

Singapore's Land Transport Master plan and Sustainable Singapore Blueprint

The Singapore Land Transport Authority Master plan details three strategic thrusts for dealing with transportation challenges in Singapore:

1) Making public transport a choice mode,
2) Managing road usage, and
3) Meeting diverse needs.

Managing road usage includes moderating vehicle population growth rate. The LTA has committed to reducing vehicle population growth rate to 0.5% from 2013 onwards. Since 2010, the growth rate of private cars has remained below 3%, dipping to 0.6% in 2014 [1].

[1] Please see Appendix D – Private Cars in Singapore for more details.

Appendix B – Singapore Government Initiatives in E-Mobility

On the 8th of December 2014, LTA issued a joint news release where Mr Yeoh Keat Chuan, Managing Director of EDB said, "The EV car-sharing programme aims to provide a sizeable platform for complementary industry players in the e-mobility ecosystem to develop, test and commercialise innovative e-mobility solutions. The pilot will help Singapore to be a regional leader in developing new technologies and innovative business models in the EVs and associated charging infrastructure landscape. This is also aligned with Singapore's position as a Living Lab to develop smart-sustainable city solutions that can eventually be exported to other cities in Asia and beyond." [1]

On the 30th of June 2016, LTA issued another joint news release where Mr Yeoh Keat Chuan, Managing Director of EDB said, "We are pleased that Bolloré Group, through BlueSG Pte Ltd, is leveraging Singapore as a key reference market in Asia to deploy its EV programme, and will thereafter serve Asia through its Asia Pacific HQ and Global Innovation Centre based here. To position Singapore as the regional leader in electric mobility and energy management technologies, the EV Car-sharing Programme will also serve as a living lab platform to attract new players to develop, test and commercialise innovative urban solutions here before scaling up for the region." [2]

[1] Land Transport Authority and Economic Development Board. (8 December, 2014). *Joint News Release by the Land Transport Authority & EDB on EV Phase 2 – Share an Electric Car*.

[2] Land transport Authority and Economic Development Board. (30 June, 2016). *JOINT NEWS RELEASE BY THE LAND TRANSPORT AUTHORITY (LTA) & EDB - ELECTRIC VEHICLES (EVS) IN EVERY HDB TOWN BY 2020*.

Appendix C – The Challenges of EV and the Global Experience

To ensure that EVs operate at their peak mechanical and electrical efficiency, it is important to ensure help is easily available for consumers in the maintenance of their EV. Taking reference from other countries which have implemented EVs in their transport infrastructure, Singapore can adopt some elements for our situation.

Case Study

The Estonia E-Mobility Programme (ELMO) – a nation of DC fast chargers

Introduction

In March 2011, the Government of the Republic of Estonia concluded a contract with Mitsubishi Corporation for the sale of Assigned Amount Units (AAUs)[1] in the amount of 10 million AAUs to start the Estonian electrical mobility programme[2] [3] (Automotive News Europe, 2011). The programme consists of three parts:

- 507 Mitsubishi iMiev electric cars were commissioned by the Ministry of Social Affairs as an example.
- The Ministry of Economic Affairs and Communications developed a support system for natural and legal persons for acquisition of electric cars.
- Infrastructure for charging electric cars was created to cover the whole country. Distribution of the purchase grant and the administration of the quick charging network is organised by Foundation KredEx. Since November 2012, the purchase of plug-charged hybrid vehicles has also been supported.

The goal of the programme is to speed up the commissioning of electric cars in Estonia, and facilitate the achievement of the goal undertaken by the state to increase the use of renewable energy by 2020.

In action

The ELMO programme was considered a crucial long-term instrument to encourage the wider adoption of EVs in the country. Financed by a CO_2 emissions trade agreement between the Estonian government and Japan's Mitsubishi Corporation under the Kyoto Protocol, the total budget for the nationwide infrastructure development and 5-year maintenance was approximately € 12m.

In order to establish this nationwide charging infrastructure, the government asked financing and programme management agency KredEx to procure a turnkey technical solution with a 5-year operational agreement from private providers. In addition, KredEx was responsible for finding and securing locations for chargers and ensuring that electricity-grid companies built sufficient power connections to those locations. All subtasks within the programme were procured from private companies.

ELMO was officially launched in mid-summer 2011 and included three main parallel processes to develop locations; grid connections; and turnkey solutions for chargers and an IT system and service set-up. The tender for the turnkey solution was won by a consortium led by multinational power engineering corporation ABB that included software partner NOW! Innovations and service operator G4S.

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[1] Parties with commitments under the Kyoto Protocol (Annex B Parties) have accepted targets for limiting or reducing emissions. These targets are expressed as levels of allowed emissions, or "assigned amounts," over the 2008-2012 commitment period. The allowed emissions are divided into "assigned amount units" (AAUs).

[2] Eltis. (31 August, 2015). *ELMO: Estonia's innovative national quick-charging EV network*.

[3] Automotive News Europe. (3 March, 2011). *Estonia approves sale of 10M carbon credits to Mitsubishi*.

Results

The ELMO network was officially opened in February 2015 and consists of 165 CHAdeMO[4]-standard quick chargers. Charging points were distributed on all roads with dense traffic; in towns with over 5,000 people; next to frequently visited locations such as petrol stations, cafes, shops and banks; and ports servicing international and local travellers. The distance between each charging station was 40-60km. Currently 100 quick-chargers are in towns – 44 in larger towns; 27 in Tallinn; 10 in Tartu; five in Pärnu and two in Narva. Sixty-five are located near roads. To pay for the charging facility, EV drivers can use the ELMO app on their mobile device, or authorise payments using a radio-frequency identification (RFID) card. In addition, 24/7 phone support is available for ELMO service subscribers.

The quick-charging network has rapidly increased in popularity over the last two years; in February 2013, it was used 1,000 times; in January 2015 that number rose to 11,000 charges a month. The system is being currently used by 1,100 regular drivers, with an average charging time of 20 minutes.

In such a case, having the right partner is important, and decisions about where to put the chargers were a compromise between analytics (road-usage) and whether locations met the eligibility criteria and were available.

[4] CHAdeMO is an abbreviation of CHArge de Move, and is the trade name of a quick-charging method for battery electric vehicles delivering up to 62.5 kW of high-voltage direct current via a special electrical connector. It is proposed as a global industry standard by an association of the same name.

Appendix D – Private Cars in Singapore

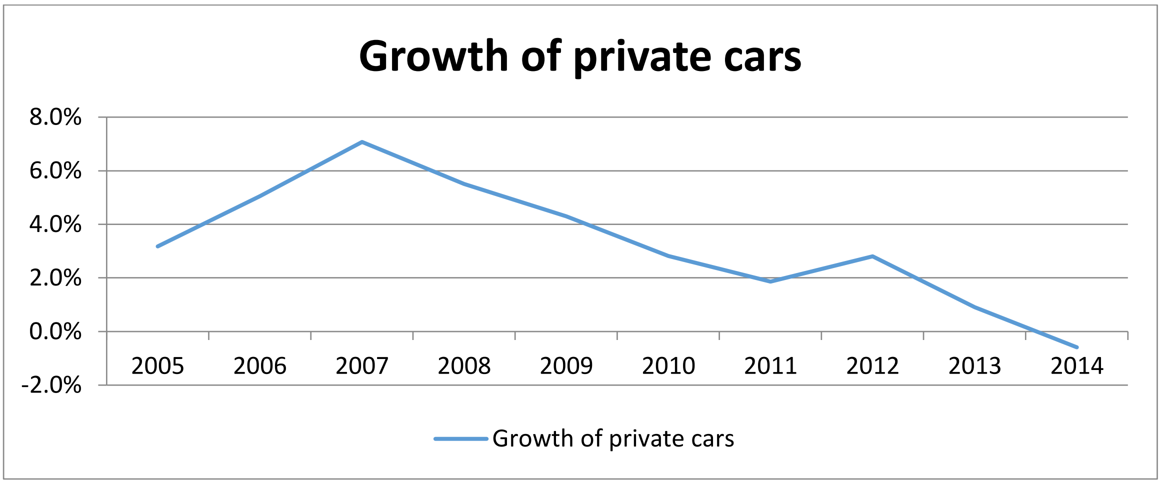


Figure 3 - % growth in number of private cars in Singapore from 2005 – 2014[1]

This is a step towards the objective of a "car-lite" Singapore, highlighted in the Sustainable Singapore Blueprint 2015. With a reduction in private car population, car sharing systems need to be further developed in order to meet the diverse needs and fulfil the lifestyle aspirations of Singaporeans in a "car-lite" Singapore.

Meeting diverse needs also includes promoting environmental sustainability. The Blueprint recognises the creation of an EV car sharing programme as a key strategy towards achieving these objectives.

Spearheaded by the Land Transport Authority (LTA) and the Economic Development Board (EDB), the EV car sharing programme will see the introduction of up to 1,000 EVs and the charging infrastructure to support their use during the initial trial period of up to 10 years.

[1] Land Transport Authority. (2015). *Annual Vehicle Statistics.*

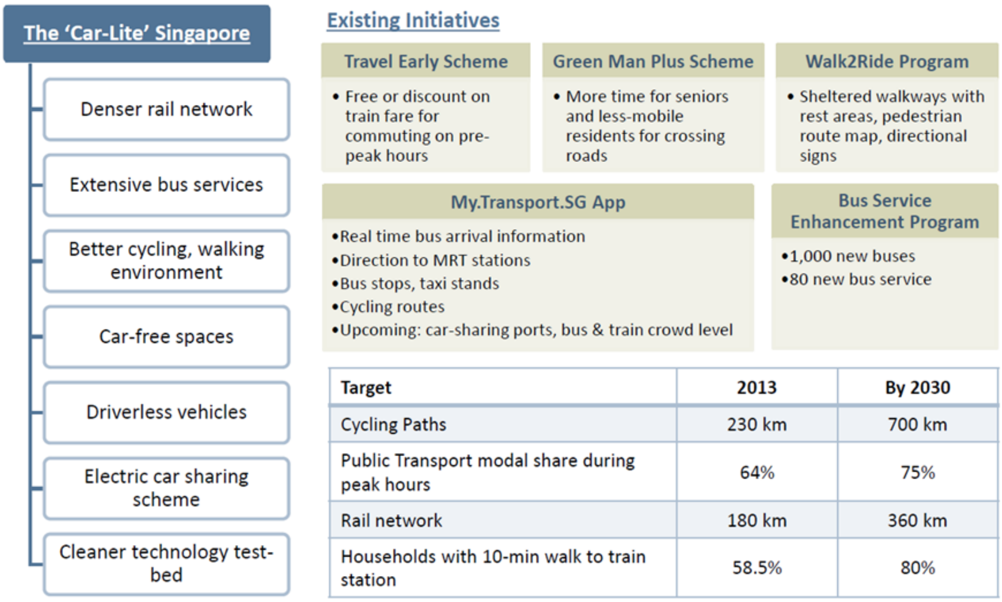


Figure 4 - The long term vision for "green and clean" of the Sustainable Singapore Blueprint sets targets on different indicators, including mobility. Source: Frost and Sullivan

The automotive industry in Singapore

Consumer preferences for car purchase

In 2014, the average annual distance driven by cars was 17,500km, a decrease of 300km from the year before.

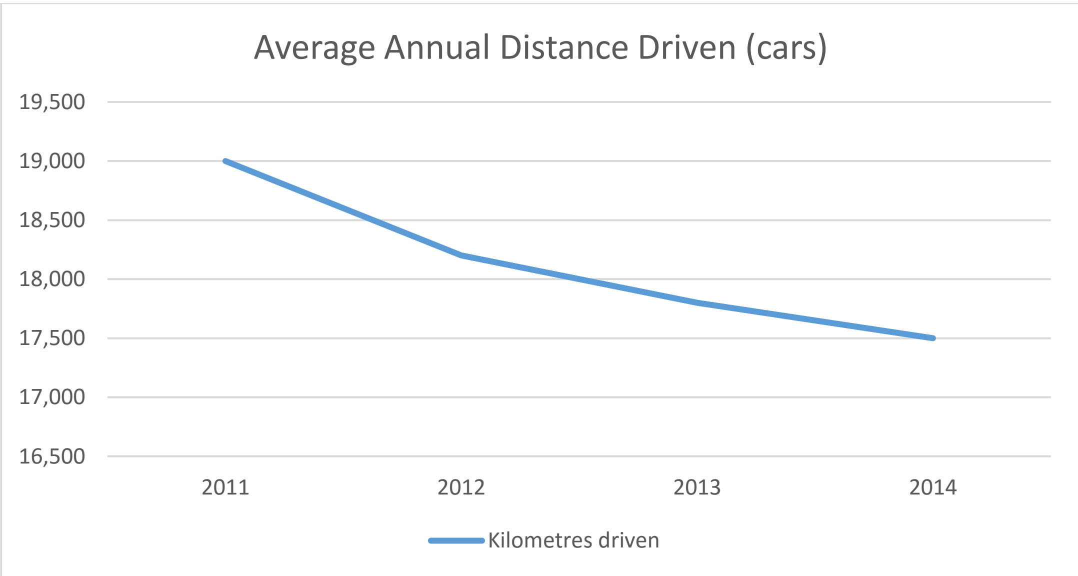


Figure 5 – Average annual distance drive by cars

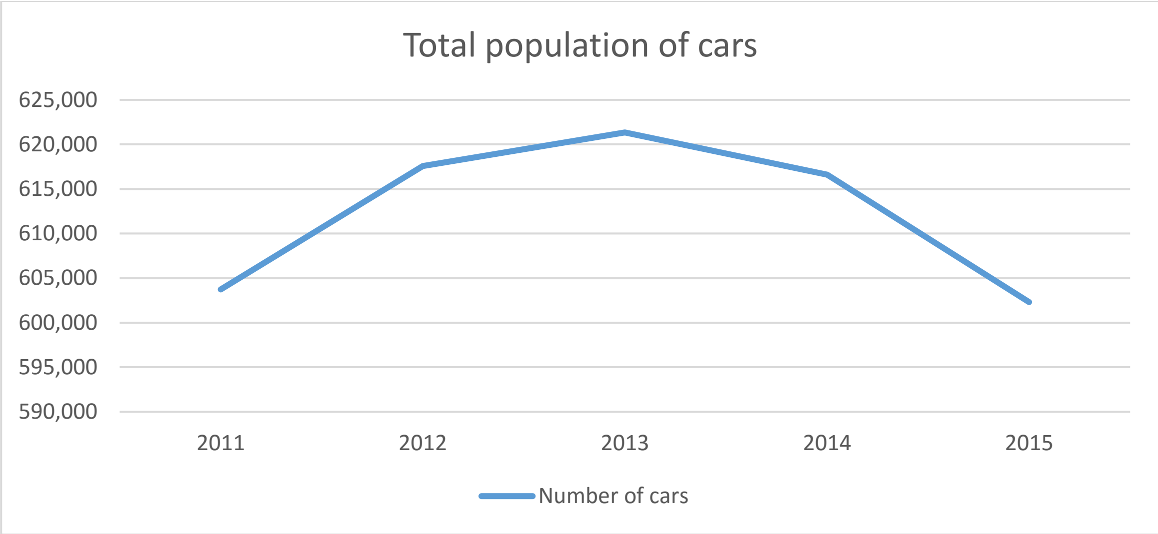
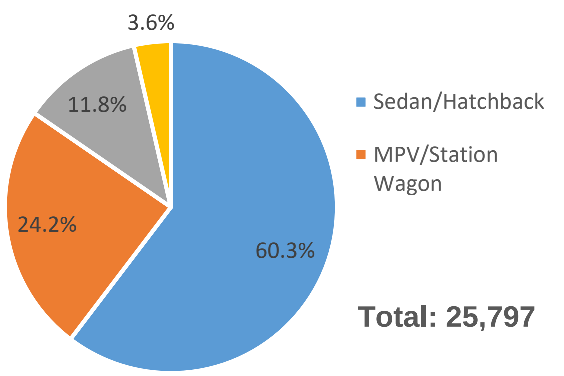


Figure 6 – Total car population in Singapore from 2011 to 2015

Based on the data presented, the average daily driving distance in 2014 is 48km per car. The study carried out from the first EV test bed places the average distance EV vehicle drive distance as 46km per day and the national average is 50km. This is easily achieved by most, if not all, electric cars offered by established manufacturers. They range between 120km to 160 km on a single battery charge.

This reinforces the idea that today's EVs are able to meet the range demands for most use-case scenarios for drivers. It should be noted that this range may vary depending on each individual's driving technique or style.

Figure 7 – New car registration by body type (YTD Jun 2015)[1].



The most popular body types of cars in Singapore are sedans and hatchbacks, followed by Multi-Purpose Vehicles (MPVs) and station wagons, then Sport Utility Vehicles (SUVs), and lastly, coupés and convertibles.

While longer drives to Malaysia may still be impractical at this juncture for most EVs, the private sector in Malaysia has announced plans in to install 300 charging stations by 2016 to ensure the cars have sufficient range [2].

If this target is achieved, Singaporean drivers may find range anxiety less of an issue in the long run following the private sector initiatives. There is therefore an opportunity to collaborate closely with on the private sector fronts to propose plans to the policy makers to fully realise the benefit of EVs on both sides of the border.

[2] BMW Malaysia Sdn Bhd. (15 August, 2015). *BMW Group Malaysia to Provide ChargEV Solutions and Services to BMW i8 Customers*.

Appendix E – Base PARF Value Calculation on ARF Value Before Rebates to Achieve Full Impact of CEVS

The preferential additional registration fee (PARF), commonly known as scrap value, of a vehicle is based on the ARF and depends on the age of the car at deregistration as shown in the table below:

Table 4 – PARF Rebate table[1]

Age at Deregistration (year)	PARF Rebate (for cars registered with COEs obtained from May 2002 tender onwards)
Not exceeding 5	75% of ARF paid
Above 5 but not exceeding 6	70% of ARF paid
Above 6 but not exceeding 7	65% of ARF paid
Above 7 but not exceeding 8	60% of ARF paid
Above 8 but not exceeding 9	55% of ARF paid
Above 9 but not exceeding 10	50% of ARF paid
Above 10	Nil

As such, the CEVS which offers a rebate on the ARF would also reduce the PARF value. This has two major implications which would likely decrease the benefit of any CEVS incentive:

1) Upon deregistration, car-owners who received a CEVS rebate (and therefore pay a lower ARF) on their low emissions car and own it till the end of the 10 year COE validity period will receive a lower PARF, than if there had been no CEVS rebate. The net gain from the CEVS for the car-owners would then only be half of the advertised rebate amounts.
2) Car-owners who similarly received a CEVS rebate on their low emissions car but sell it before the end of the 10 year COE validity period will have to contend with lower willingness-to-pay in the resale car market due to the lower PARF value available to resale car buyers.

Therefore, to achieve the full impact of the CEVS in enticing would-be car buyers to purchase low emissions cars, the PARF value of cars which received the CEVS rebate should be based on the ARF value before the rebates, not after.

[1] ONE.MOTORING. (n.d.). *PARF/COE REBATES*.

Appendix F – EV Models in the market

EV models currently on the market

The following table provides a non-exhaustive list of currently available EV and Plug-in Hybrid Electric Vehicle (PHEV) automobiles made by mainstream manufacturers available globally.

Table 5 – List of EV and PHEV vehicles available globally (EPRI, 2016)

Model Name	Plug-in Type	Body Style	Range (miles)
BMW i3	Battery electric vehicle	Hatchback	81
BMW i3 Rex	Plug-in hybrid	Hatchback	72/150
BMW i8	Plug-in hybrid	Sport coupe	15/330
BMW X5 xDrive40e	Plug-in hybrid	hybrid SUV	14/540
Cadillac ELR	Plug-in hybrid	Luxury sedan	40/340
Chevrolet Volt	Plug-in hybrid	Compact	53/420
Ford C-MAX Energi	Plug-in hybrid	Hatchback	20/550
Ford Focus Electric	Battery electric vehicle	Hatchback	76
Ford Fusion Energi	Plug-in hybrid	Sedan	20/550
Mitsubishi i-MiEV	Battery electric vehicle	Subcompact	62
Nissan LEAF	Battery electric vehicle	Hatchback	107
Porsche Cayenne S E-Hybrid	Plug-in hybrid	Crossover	14/480
Porsche Panamera S E-Hybrid	Plug-in hybrid	Luxury sedan	16/560
Tesla Model S	Battery electric vehicle	Luxury sedan	234-270
Tesla Model X	Battery electric vehicle	Crossover	250-257
Volvo XC90 T8 Twin Engine	Plug-in hybrid	SUV	14/350
Audi A3 Sportback e-tron	Plug-in hybrid	Hatchback	16/380
Chevrolet Spark	Battery electric vehicle	Compact hatchback	82
Fiat 500e	Battery electric vehicle	Subcompact	87
Hyundai Sonata	Plug-in hybrid	Sedan	27/600
Kia Soul EV	Battery electric vehicle	Compact SUV	93
Mercedes-Benz B250e	Battery electric vehicle	Hatchback	87
Mercedes-Benz S550e	Plug-in hybrid	Luxury sedan	14/450
smart fortwo electric drive	Battery electric vehicle	Subcompact	68
Volkswagen e-Golf	Battery electric vehicle	Hatchback	83

Appendix G – Road Tax

Table 6 – Road tax for different vehicles types

Road Taxes excluding Feb '15-announced rebates	Road tax based on	Power Output (kW)	Annual Road Tax (before rebates)	Annual Road Tax (after rebates 1 Aug 2015 – 31 Jul 2016)
Honda Civic 1.6 (Petrol)	Engine capacity	92	S$742	S$636
BMW 316i (Petrol)	Engine capacity	100	S$742	S$636
BMW i3 (REx) (EV)	Electric motor output	125	S$1,776	S$1,522
BMW i8 (EV)	Both powertrains	266	S$1,231	S$1,056

*Calculation of the road tax is based on different entities.

To increase the adoption of electrical vehicles, the road tax should be re-examined for it to be on par with fossil fuel based vehicles. The current disparity between the 2 different technologies is too wide, which dissuades adoption of electrical vehicles.

Appendix H – Bus Services in Singapore

Private Bus Services

The private bus sector is facilitated and regulated by the Land Transport Authority of Singapore. According to its definitions, there are five categories of private buses, namely the private hire bus, private bus, excursion bus, school bus and the ASEAN Member Country-Registered Bus.

Public Bus Services

Increasing the appeal of public transport has always been a key strategy for CO_2emission reduction. This is one of the motivations behind setting the peak hour transport mode target at 75 percent in the Land Transport Master Plan 2013[1]. Public transport is deemed as the most space-efficient and environmentally-sustainable option for Singapore. To meet the public transit demand in the future, the Bus Service Enhancement Programme (BSEP) was announced in 2012, to put more buses on the roads – 1,000 government-funded buses to operate by the year 2017. With the increasing emphasis on public buses as the choice-mode of urban transit, therein lies a niche for alternative vehicles, such as electric buses, which are more cost effective to operate.

[1] Land Transport Authority. (1 October, 2014). *Making Public Transport the Choice Mode*.

Appendix I – Comparison of Buses

The comparison of the bus categories is summarised in the following table.

Table 7: Categories of Private Buses

Private Hire Bus	• Most commonly used to ferry adult workers to and from work. • May also be used to ferry school children and staff. • Registered under individual or company • COE cat C or E
Private Bus	• Used to ferry employees of business owner at no profit • Registered under company's name • COE cat. C or E
Excursion Bus	• Carry tourists, where passengers use unscheduled service and are charged separate and distinct fares • Can also be used for chartering purpose • Can be used to ferry workers and school children • COE cat. C or E
School Bus	• Ferry school children and staff • Can be used to ferry workers if Adult Workers Contract (AWC) permit is granted • Cannot be used to ferry tourists • Registered under company or individual • No COE requirement
ASEAN Member Country-Registered Bus	• Must apply for a public service vehicle permit to operate • Used for scheduled service, to ferry tourists, workers, students • No COE required

There are a total of 12,620 private buses in operation as of 2015 (refer to Table 8 – Bus Population by Vehicle Type). This makes up about 71% of the total number of buses on the road. According to the Singapore School and Private Hire Bus Owners Association (SSPHBOA), there are over 1,800 operators in those categories with a combined fleet of more than 5,000 buses [1] . The mix of bus types in operation are shown in Figure 8 – Breakdown of buses in Singapore.

Table 8 – Bus Population by Vehicle Type (Land Transport Authority, 2015)

End of Period (Year)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Public Buses	3599	3785	3761	3854	4045	3981	4112	4212	4552	4756	5120
School Buses	1973	1881	1851	1852	1849	1845	1844	1839	1847	1845	1847
Private Buses	2557	2577	2628	2739	2795	2842	3076	2968	2871	2802	2717
Private Hire Buses	3090	3189	3356	3548	3586	3507	3332	3063	2654	2152	1909
Excursion Buses	2101	2399	2596	2983	3384	3761	4288	4686	5141	5554	6147
Total Private	9721	10046	10431	11122	11614	11955	12540	12556	12513	12353	12620

[1] Singapore School & Private Hire Bus Owners' Association. (2015). *SSPHBOA*.

Of all the buses in Singapore, 99 per cent use diesel as fuel. Moreover, there are only four diesel-electric hybrids as of 2015[2]. Diesel buses are expensive for bus operators to run due to the high costs of fuel and maintenance. Also, buses travel very long distances, easily covering three times the mileage of a car in a year. In 2014, on average, private hire buses travelled 54,400 km per vehicle whereas cars travelled 17,500 km per vehicle[3]. For a bus covering a mileage of 300 km/day on 300 days a year, the cost of fuel is estimated at SGD$28,800 – SGD$41,236 (depending on low or high fuel costs) while the cost of maintenance is around SGD$150,000[4]. Therefore, it would be in the interest of private bus operators to switch to vehicles which use an alternative fuel source which is more cost effective to operate, such as electricity for electric hybrid buses.

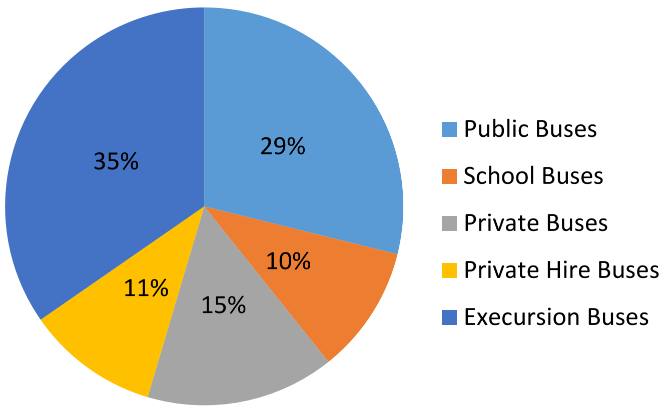


Figure 8 – Breakdown of buses in Singapore

[2] Land Transport Authority. (2015). *Motor Vehicle Population by Type of Fuel Used.*
[3] Land Transport Authority. (2015). *Land Transport Statistics in Brief 2015.*
[4] Based on actual data provided by bus operators (for estimate figures, see Tables 9 & 10)

Capital and Operational Expenditure of Buses in Singapore

Table 9: CAPEX & OPEX Comparison, in Singapore Dollars (Low Fuel Cost Scenario)[5]

CAPEX		Diesel Coach	Diesel OMNI	Low-Entry Electric OMNI	
		Private	Public	without COE	with COE
BUS	New Bus	185,000	330,000	350,000	395,000
	COE	45,000	0	0	45,000
INFRASTRUCTURE	Battery Charger	0	0	22,500	22,500
TOTAL $		230,000	330,000	372,500	462,500

OPEX		Basis	Mileage/year	300 km/day x 300 days/year				
				90,000		km		
		Diesel Coach		Diesel OMNI		Low-Entry Electric OMNI		
		Private	Units	Public	Units	(Regardless of COE)		Units
Fuel/Energy	Consumption	0.36	L/km	0.40	L/km	1.25		kWh/km
	Cost	0.88	$/L	0.88	$/L	Peak	0.17	$/kWh
						Off-Peak	0.11	$/kWh
	Sub Total $	28,800		31,680		[6]Ratio 3:2	16774	
Maintenance	Sub Total $	150,000				110,000		
TOTAL $		178,800		181,680		126,774		

Table 10: CAPEX & OPEX Comparison, in Singapore Dollars (High Fuel Cost Scenario)

CAPEX		Diesel Coach	Diesel OMNI	Low-Entry Electric OMNI	
		Private	Public	without COE	with COE
BUS	New Bus	185,000	330,000	350,000	395,000
	COE	45,000	0	0	45,000
INFRASTRUCTURE	Battery Charger	0	0	22,500	22,500
TOTAL $		230,000	330,000	372,500	462,500

OPEX		Basis	Mileage/year	300 km/day x 300 days/year				
				90,000		km		
		Diesel Coach		Diesel OMNI		Low-Entry Electric OMNI		
		Private	Units	Public	Units	(Regardless of COE)		Units
Fuel	Consumption	0.36	L/km	0.40	L/km	1.25		kWh/km
	Cost	1.26	$/L	1.26	$/L	Peak	0.30	$/kWh
						Off-Peak	0.19	$/kWh
	Sub Total $	41,236		45,360		Ratio 3:2	29254	
Maintenance	Sub Total $	150,000				110,000		
TOTAL $		191,236		195,360		139,254		

[5] Estimates are based on actual data provided by bus operators
[6] Peak: Off-Peak Ratio

Table 11: Return of Investment Comparison, in Singapore Dollars (Low Cost Scenario)

Comparison	CAPEX	OPEX	ROI (years)
	NET SAVINGS		
Diesel Coach Vs E OMNI w/o COE	-142,500	52,026	2.74
Diesel Coach Vs E OMNI w/ COE	-232,500	52,026	4.47
Public OMNI vs E OMNI w/o COE	-42,500	54,906	0.77
Public OMNI vs E OMNI w/ COE	-132,500	54,906	2.41

Table 12: Return of Investment (High Cost Scenario)

Comparison	CAPEX	OPEX	ROI (years)
	NET SAVINGS		
Diesel Coach Vs E OMNI w/o COE	-142,500	51,983	2.74
Diesel Coach Vs E OMNI w/ COE	-232,500	51,983	4.47
Public OMNI vs E OMNI w/o COE	-42,500	56,106	0.76
Public OMNI vs E OMNI w/o COE	-132,500	56,106	2.36

Appendix J – Regulations & Measures for Petrol and Diesel Vehicle Emissions

Motor vehicles are the one of the major sources of air pollution in Singapore and are strictly regulated by the National Environmental Agency on emission standards. The primary ways with which emissions are regulated are through abatement measures:

1) Vehicular Emission Standards
2) Fuel Quality Standards
3) Mandatory Inspections
4) Enforcement Against Smoky Vehicles (Pollution Control Department)

In 2012, the NEA declared higher air quality targets by 2020.

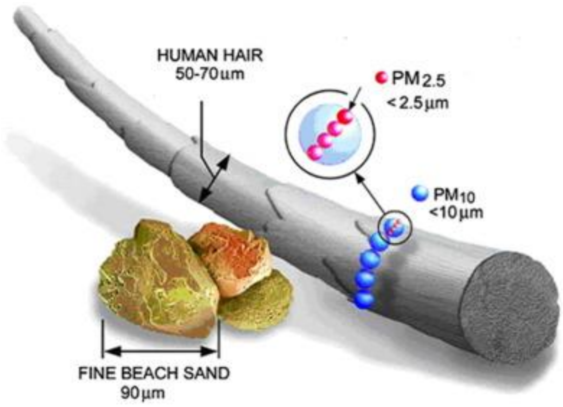


Figure 9 - Relative size of PM2.5 and PM10

Vehicular Emission Standards & Fuel Quality Control

Effective from 2014, diesel and petrol vehicles emission standards have been tightened to Euro V [1] [2] and Euro VI standards [3] [4] respectively. For petrol, standards will be further tightened to EURO V by 2017. Diesel vehicles must meet an additional smoke opacity limit of 40 Hartridge Smoke Units. In Dec 2014, the NEA announced that from 2018, diesel vehicles must comply with EURO VI emission standards, the latest set by the European Union [5].

The fuel quality specifications are show in table 15. Companies will be in compliance of the fuel standards above in their entirety by 2018.

[1] European Parliament and of the Council. (13 October, 1998). *EUR-Lex - 31998L0069 - EN*.
[2] United Nations Economic Commission for Europe. (14 June, 2002). *Current and Future European Community Emission Requirements.*
[3] European Parliament and of the Council. (28 September, 2005). *EUR-Lex - l24282 - EN.*
[4] European Parliament and of the Council. (20 June, 2007). *EUR-Lex - 32007R0715 - EN.*
[5] National Environment Agency. (30 December, 2014). *Singapore Will Usher in Euro VI Emission Standard for Diesel Vehicles from January 2018.*

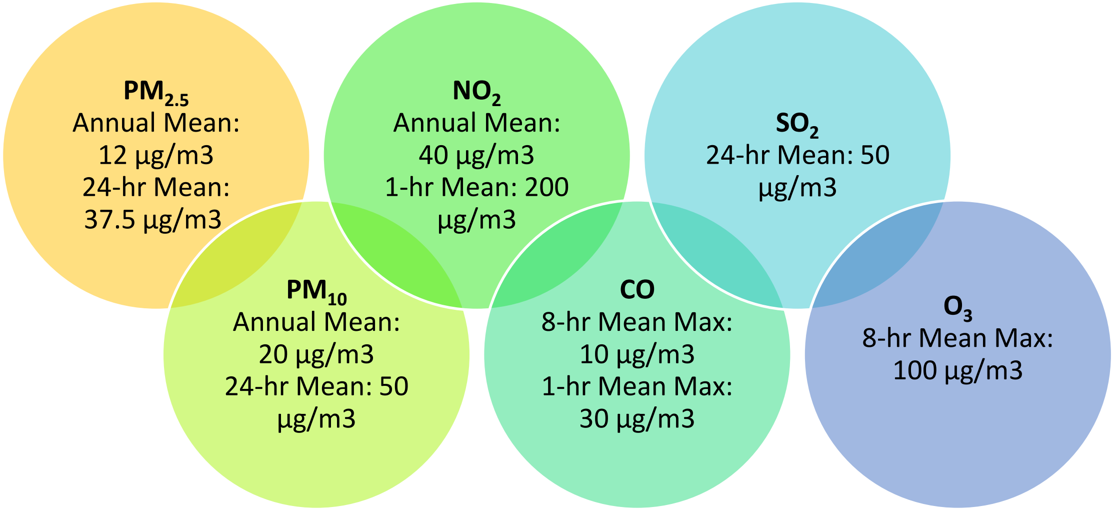


Figure 10: NEA Air Quality Targets 2020 at a Glance

Table 13: Health Implications of Pollutants and Guidelines [6] [7]

Pollutants in ICEV Emission	Health Implication	Guidelines
Particulate Matter (PM)[8]	Microscopic particles which can go deep into the lungs get trapped and cause irritation. Can serve as a vector for other toxic air pollutants (see below)	$PM_{2.5}$ 10 µg/m^3 annual mean 25 µg/m^3 24-hour mean PM_{10} 20 µg/m^3 annual mean 50 µg/m^3 24-hour mean
Hydrocarbon (HC)	Precursor to Ozone formation together with NO_x	-
Nitrogen Oxides (NO_x)	Precursor to Ozone formation together with HC. Similar health effects to ozone and sulphur dioxide	NO_2 40 µg/m^3 annual mean 200 µg/m^3 1-hour mean

[6] Washington State Department of Ecology. (December, 2001). *Health Effects from Automobile Emissions.*
[7] World Health Organisation. (March, 2014). *Ambient (outdoor) air quality and health*.
[8] $PM_{2.5}$ is particularly the most dangerous form of air pollutant emitted from the tailpipe of an ICEV.

Pollutants in ICEV Emission	Health Implication	Guidelines
Carbon Monoxide	Interferes with the bloods ability to carry oxygen. Insufficient oxygen to vital organs can become life threatening especially to unborn or new-born children and people with heart disease. Even healthy people can experience symptoms such as mild headache and reduced reflexes.	-
Sulphur dioxide (SO_2)	Causes irritation of the eyes and inflammation of the respiratory tract. Aggravates asthma and chronic bronchitis and makes lungs are more susceptible to infection.	SO_2 20 μg/m^3 24-hour mean 500 μg/m^3 10-minute mean
Ozone	Ground Level Ozone (smog) is produced when NO_x reacts with hydrocarbons in the presence of sunlight. Ozone can damage lung tissue and cause breathing difficulties, coughing and chest pain	O_3 100 μg/m^3 8-hour mean (daily mortality rises by 0.3% and that for heart diseases by 0.4%, per 10 μg/m^3 increase in ozone exposure)
Other Toxic Air Pollutants	Examples include benzene and formaldehyde which are carcinogens. Can cause serious illness, birth defects and genetic mutation even at very low levels. Often carried by PM which acts a vector.	-

Table 14 – Singapore Air Quality Target 2020

Pollutant	Singapore Targets by 2020	Long Term Targets
Sulphur Dioxide (SO_2)	24-hour mean: 50μg/m^3	24-hour mean: 20μg/m^3
	(WHO Interim Target)	(WHO Final)
	Annual mean: 15 μg/m^3	
	(Sustainable Singapore Blueprint target)	
Particulate Matter (PM2.5)	Annual mean: 12μg/m^3	Annual mean: 10μg/m^3

Pollutant	Singapore Targets by 2020	Long Term Targets
	Annual target of 12$\mu g/m^3$ will be retained and aligned with WHO interim Target of 37.5 $\mu g/m^3$ for 24-hour mean	
	24-hour mean: 37.5$\mu g/m^3$	
	(WHO Interim Target)	24-hour mean: 25$\mu g/m^3$ (WHO Final)
Particulate Matter (PM10)	Annual mean: 20 $\mu g/m^3$	
	24-hour mean: 50 $\mu g/m^3$	
	(WHO Final)	
Ozone	8-hour mean: 100$\mu g/m^3$	
	(WHO Final)	
Nitrogen Dioxide (NO_2)	Annual mean: 40$\mu g/m^3$	
	1-hour mean: 200$\mu g/m^3$	
	(WHO Final)	
Carbon Monoxide (CO)	8-hour mean: 10mg/m^3	
	1-hour mean: 30mg/m^3	
	(WHO Final)	

Table 15 - Petrol Specifications [9]

Petrol Property	Singapore Specification (from Jul 2017)
Sulphur, max (ppm)	10
Aromatics, max (vol%)	35% v/v (pool average, max) 42% v/v (cap limit, max)
Olefins, max (vol%)	18% v/v (pool average, max) 21% v/v (cap limit, max)
Benzene, max (vol%)	1
Lead, max (g/L)	0.005
Oxygen content, max (wt%)	3.7
Oxygenates **- Ethers (>= C5), vol%, max**	22
Reid Vapour Pressure @ 37.8 °C, max (kPa)	60
Distillation **- Evaporated at 100 °C, min (%v/v)** **- Evaporated at 150 °C, min, (%v/v)**	46.0 75.0

[9] National Environment Agency. (4 March, 2014). *Factsheet on Singapore Air Quality Abatement Measures.*

Table 16 - Diesel Specifications [9]

Diesel Property	Singapore Specification (from 1 Jan 2017)
Sulphur, max (ppm)	10
Cetane Number, min	51
Density @ 15°C, max (kg/m^3)	845
Polyaromatics, max (wt%)	8
T95, max (°C)	360

Table 17: Emission Limits of Pollutants [10]

Substance	*Trade, industry, process, fuel burning equipment or industrial plant*	*Emission limits*
(*d*) Benzene	Any trade, industry or process	5 mg/Nm^3
(*f*) Carbon monoxide	Any trade, industry, process or fuel burning equipment	250 mg/Nm^3
(*l*) Formaldehyde	Any trade, industry or process	20 mg/Nm^3
(*o*) Lead and its compounds	Any trade, industry or process	0.5 mg/Nm^3 expressed as lead
(*q*) Oxides of nitrogen	Any trade, industry, process or fuel burning equipment	400 mg/Nm^3 expressed as nitrogen dioxide
(r) Particulate substances including smoke, soot, dust, ash, fly-ash, cinders, cement, lime, alumina, grit and other solid particles of any kind	Any trade, industry, process, fuel burning equipment or industrial plant (except for any cold blast foundry cupolas)	(i) 50 mg/Nm3; or (ii) where there is more than one flue, duct or chimney in any scheduled premises, the total mass of the particulate emissions from all of such flue, duct or chimney divided by the total volume of such emissions shall not exceed 50 mg/Nm3 and the particulate emissions from each of such flue, duct or chimney shall not exceed 100 mg/Nm3 at any point in time.
(*t*) Sulphur dioxide (non-combustion sources)	Any trade, industry or process	500 mg/Nm^3
(*ta*) Sulphur dioxide (combustion	Any trade, industry or process	(i) 1,700 mg/Nm3
(*u*) Sulphur trioxide and other acid gases	The manufacture of sulphuric acid	500 mg/Nm^3 expressed as sulphur trioxide. Effluent gases shall be free from persistent mist.
(*v*) Sulphur trioxide or sulphuric acid mist	Any trade, industry or process, other than any combustion process and any plant involving the manufacture of sulphuric acid	100 mg/Nm^3 expressed as sulphur trioxide

[10] Singapore Statutes Online. (1 July, 2015). *Standards of Concentration of Air Impurities*.

Appendix K – Battery Related Challenges

In Singapore's context, the range of most EVs is acceptable as the average daily mileage of private cars in Singapore is less than 50km (2014: 17,500km/year). Plug-in hybrid electric vehicles (PHEVs) with a higher range with the additional combustion engine could be the bridge to going completely electric. In most cases (average) the electric range of the battery would be enough with 50km per charge.

Charging facilities for overnight charging at home are more important than a wide-spread network island-wide. The network is more to reduce range anxiety of customers. Therefore, the installation process of home charging facilities must be improved.

- **Driving range:** most EVs can only go about 160 – 320 kilometres before recharging—gasoline vehicles can go over 480 kilometres before refuelling.
- **Recharge time:** fully recharging the battery pack can take 4 to 8 hours. Even a "quick charge" to 80% capacity can take 30 min.
- **Battery cost:** large battery packs are expensive and may need to be replaced one or more times.
- **Bulk & weight:** battery packs are heavy and take up considerable vehicle space.
  However, researchers are working on improved battery technologies to increase driving range and decrease recharging time, weight, and cost. These factors will ultimately determine the future of EVs.

Appendix L – Charging Standards

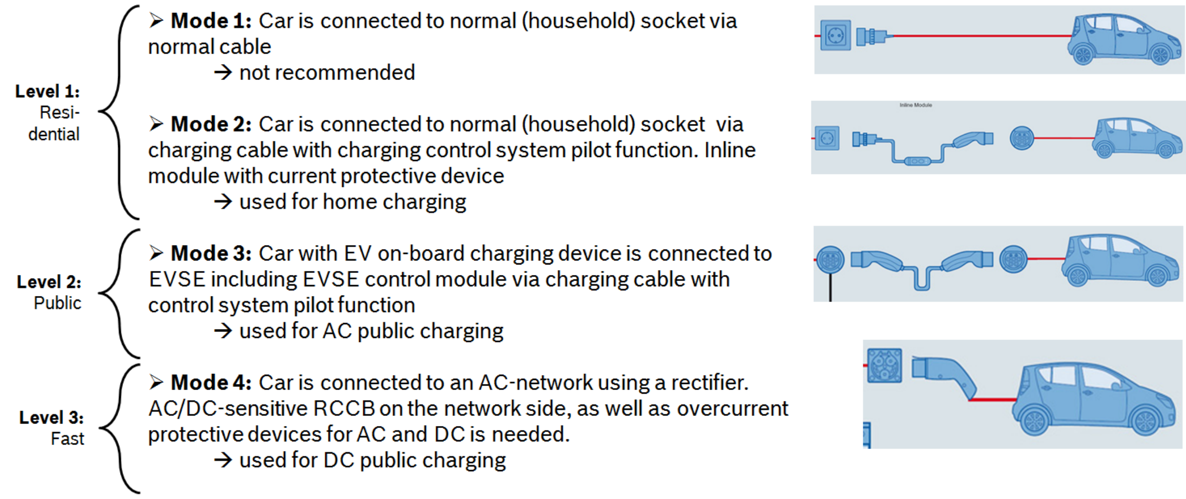
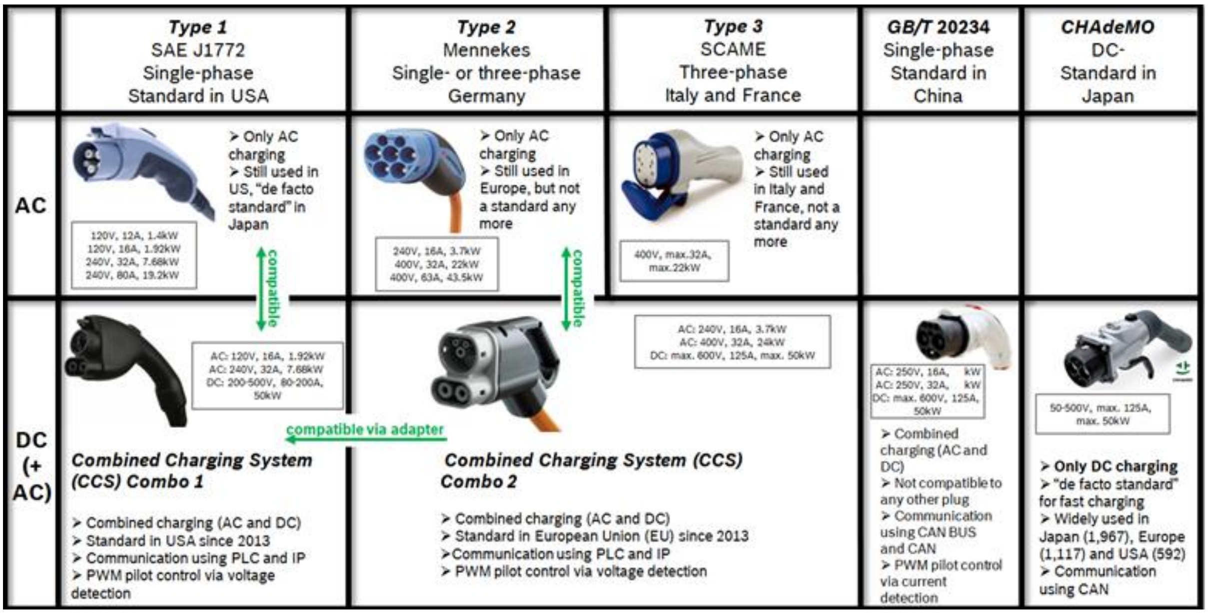


Figure 11 – Different charging levels and modes for electrical vehicles



	Type 1 SAE J1772 Single-phase Standard in USA	***Type 2*** Mennekes Single- or three-phase Germany	***Type 3*** SCAME Three-phase Italy and France	***GB/T 20234*** Single-phase Standard in China	***CHAdeMO*** DC- Standard in Japan
AC	➢ Only AC charging ➢ Still used in US, "de facto standard" in Japan 120V, 12A, 1.4kW 120V, 16A, 1.92kW 240V, 32A, 7.68kW 240V, 80A, 19.2kW compatible	➢ Only AC charging ➢ Still used in Europe, but not a standard any more 240V, 16A, 3.7kW 400V, 32A, 22kW 400V, 63A, 43.5kW compatible	➢ Only AC charging ➢ Still used in Italy and France, not a standard any more 400V, max.32A, max.22kW		
DC (+ AC)	AC: 120V, 16A, 1.92kW AC: 240V, 32A, 7.68kW DC: 200-500V, 80-200A, 50kW ***Combined Charging System (CCS) Combo 1*** ➢ Combined charging (AC and DC) ➢ Standard in USA since 2013 ➢ Communication using PLC and IP ➢ PWM pilot control via voltage detection	compatible via adapter AC: 240V, 16A, 3.7kW AC: 400V, 32A, 24kW DC: max. 600V, 125A, max. 50kW ***Combined Charging System (CCS) Combo 2*** ➢ Combined charging (AC and DC) ➢ Standard in European Union (EU) since 2013 ➢Communication using PLC and IP ➢ PWM pilot control via voltage detection		AC: 250V, 16A, kW AC: 250V, 32A, kW DC: max. 600V, 125A, 50kW ➢ Combined charging (AC and DC) ➢ Not compatible to any other plug ➢ Communication using CAN BUS and CAN ➢ PWM pilot control via current detection	50-500V, max. 125A, max. 50kW ➢ **Only DC charging** ➢ "de facto standard" for fast charging ➢ Widely used in Japan (1,967), Europe (1,117) and USA (592) ➢ Communication using CAN

Figure 12 – Type of charging plug types for different countries

Appendix M – Charging Infrastructure

Table 18 – Types of Charging Stations Available in Singapore

Type		Description	Electrical Power	Charging Duration
Normal Charger	**Mode 2 Residential**	Installed in private properties	3 kW	7-8 hours
	Mode 3 Public	Installed in shopping centres and HDB carparks		
Quick Charger		Short-time & High-Power Charging Alternative	30-50 kW	30-45 min

Figure 13: Public Indoor Charging Station [1] (left) & Outdoor Charging Station [2] (right)

Both stations are equipped with SAE J1772 standard compliant plugs. Currently, Singapore uses Type 1 standard for normal and CHAdeMO standards for fast charging stations.

[1] Land Transport Authority. (8 October, 2010). *Factsheet on Electric Vehicles.*
[2] Bosch Software Innovations. (9 May, 2011). *Bosch eMobility Services.*

Appendix N – Carbon Emissions

The method to calculate the CO_2 figures for a car is as follows:

Measurement of carbon emission of vehicle

The carbon emission of a vehicle shall be measured or calculated in grams of carbon dioxide per kilometre driven.

Method of determining carbon emission level

(1) The carbon emission level of a vehicle shall be measured in accordance with the provisions of UNECE Regulation No. 101 or EC Directive 80/1268/EEC.

(2) The carbon emission level of a vehicle shall be that as set out:

(*a*) In the carbon dioxide emissions data which are submitted to the Registrar under section 41(*a*)(ii) of the Energy Conservation Act 2012 (Act 11 of 2012); or
(*b*) Where the Registrar requires a motor vehicle to be sent for any test or inspection, in the result of such test or inspection.

To calculate the emissions from EVs and PHEVs, the "Method of determining carbon emission level" is designed to include the CO_2 produced by the power plants, using the grid emission factor.

Comparing three different vehicles, one ICEV, one EV and one PHEV, we can see the difference in the carbon emission level from that accepted by the LTA:

Table 19 – CO_2 test emission results

Car Model	Test report according to Manufacturer/UN ECE R101	Fuel Economy Labelling Scheme (FELS) according to LTA	Difference
Honda Civic 1.6	162g/km	162g/km	0
BMW 316i	137g/km	137g/km	0
BMW i3 (REx)	13g/km	80g/km	67g/km
BMW i8	49g/km		

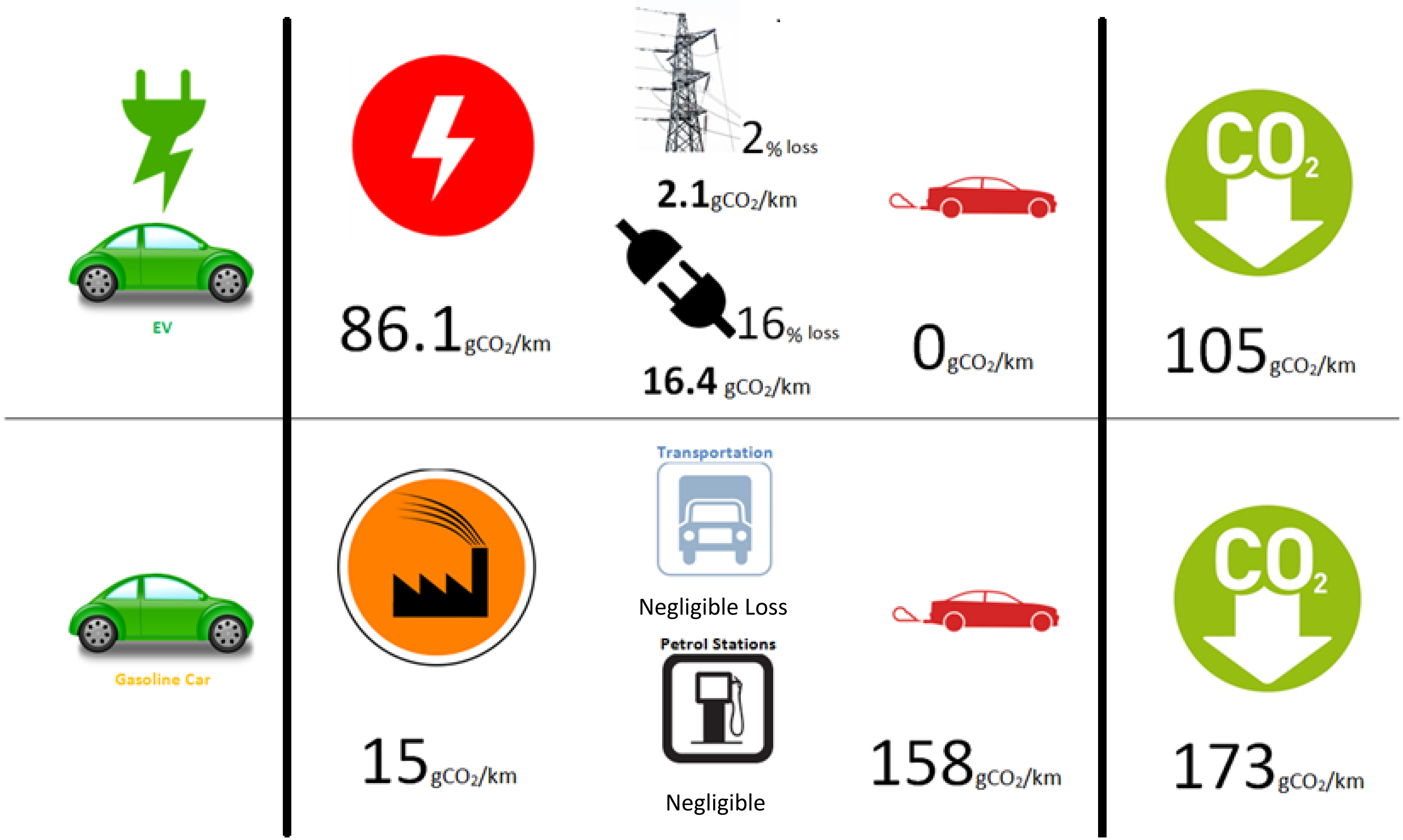


Figure 14: Electric vs Gasoline Passenger Car Emission Comparison. Boundaries for calculation is defined as the borders of Singapore (Source: DNV GL)

Appendix O – Vehicle to Grid Technology

EVs also enable vehicle to grid (V2G) technology, which enables the car to feed energy back into the power grid or adjust its charging rate based on the stability of the grid and the electricity price. However, it needs a charging station and an EV that are equipped for this technology. Note that V2G is currently not being commercialised and that Singapore's electricity market structure does not allow feeding energy back into the grid without an energy provider licence (apart from non-contestable residential customers).

As more renewable power plants such as solar panels or wind turbines are connected to the grid, it becomes less stable, as these power sources are intermittent. V2G technology can stabilise the grid by offering the necessary storage capacity in case of excessive supply or fast power supply in case of excessive demand. If the renewable power is produced in the same building, V2G technology can store the locally produced energy, thereby minimising the impact of decentralised renewable power plants on the grid.

By trading energy, the owner of the EV can utilise the battery, which is a costly component of the vehicle, to earn some revenue and lower the total cost of ownership of the vehicle. How much revenue can be earned depends largely on the electricity price spread on an average day.

All these are hassle-free for EV owners. The grid operator could take the role of informing the individual EVs and coordinating the amount of electricity to demand whenever electricity is required. This connectivity could be done through internet connection, power line carrier or a cell phone network.

Even if the infrastructure does not allow for energy to be transferred back into the grid, as is currently the case, linking all charging stations through the internet can be beneficial. In case of excessive demand, the charging stations can reduce the charging rate or even stop charging temporarily to lower the demand and likewise charge a lot when there is enough supply and electricity is cheap.

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