DIFFERENTIAL ASIA PRESENTS

THE ROAD TO ELECTRIC VEHICLES IN SINGAPORE

Part 1: Policies and Governance

POLICIES AND GOVERNANCE

Countries are increasingly adopting transport electric vehicles (EVs), with goals of phasing out internal combustion engine (ICE) vehicles in the coming years. Singapore is no different; we plan on phasing out ICE vehicles by 2040 to shift our vehicles to a cleaner fleet.

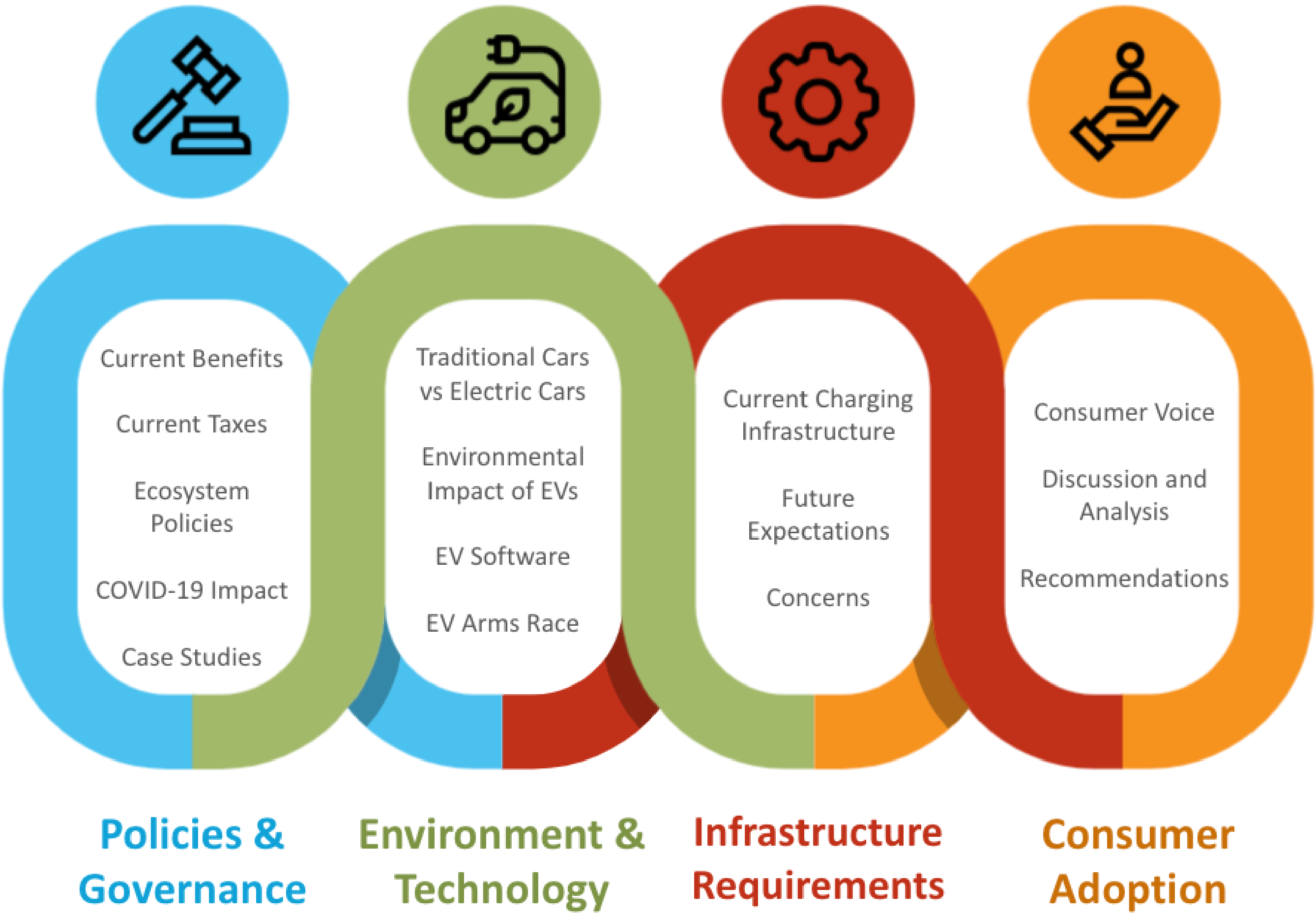
The road to understanding the EV ecosystem is long and complex — so take a seat, buckle in, and let us take this journey with you. In this article, we will be looking at the various local policies set in place to encourage adoption of electric vehicles (EVs).

differential

Differential Asia is a leading automotive consulting firm that provides advice and recommendations on concerns such as customer centricity and operational effectiveness.
Recognising the increasing relevance of electric vehicles, we decided to compile an educational report on electric vehicles in Singapore to provide a holistic understanding of the local electric vehicle scene.

OVERVIEW

Differential Asia has written four articles regarding the Singapore EV ecosystem, as seen in the image below.



What exactly are electric vehicles? If you live in Singapore, you have probably seen the easily recognisable BlueSG cars on the highway or heard about the plan to phase out ICE vehicles (vehicles with internal combustion engines – i.e. petrol or diesel vehicles) by 2040. Earlier this year, it was also announced that no diesel cars and taxis are allowed to be registered in Singapore from the year 2025. This means that private and public transportation alike need to start switching to greener vehicles in the approaching years. The clock is ticking, with several changes being made to the local transport landscape to account for these environmental goals — we then need to ask ourselves: what do we really know about electric vehicles?

CONTENT PAGE

A BRIEF HISTORY OF

ENVIRONMENT POLITICS

DIFFERENTIAL ASIA TAKES A LOOK AT SIGNIFICANT HISTORICAL FIGURES AND EVENTS THAT SHAPED THE GLOBAL STANCE ON SUSTAINABILITY.

1993

Al Gore. then-Vice President of USA, **pushes for government implementation** of environment policies such as a carbon tax to reduce usage of fossil fuels.

1997

The **Kyoto Protocol** is adopted. It is based on the United Nations Framework Convention on Climate Change with the goal of reducing greenhouse gases (GHG) emissions.

1998

Dr James Hansen presents data on climate change and GHG emissions to the US Senate Committee on Energy and Natural Resources. At that time, **his testimony was largely met with scepticism.**

2005

In a presentation to the American Geophysical Union, **Dr James Hansen** stated, "we are on the precipice of climate system **tipping points** beyond which **there is no redemption**".

2007

An Inconvenient Truth, a movie featuring Al Gore's famed slideshow on climate change, **grossed over USD$49 million worldwide.** It is regarded as a very influential film that **sparked global conversation** on global warming.

2009

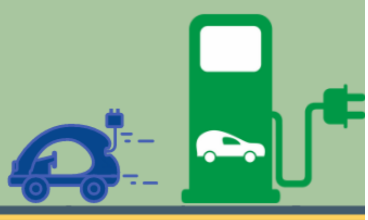
Then US-President **Barack Obama** vows to put US at the forefront of the battle against climate change. This is regarded as the **political tipping point** that spurred global conversation into action.

2015

The **Paris Agreement** is signed, with 175 out of 195 countries pledging to keep the rise in global average temperature **well below 2°C.**

2018

The **UN 2030 Agenda for Sustainable Development** announces **17 Sustainable Development Goals** that countries base their environment policies off.



1. WHY THE MOVE TOWARDS ELECTRIC VEHICLES?

Thought of moving towards global sustainable development was tentatively formed some 30 years ago, before finally sparking into a global conversation that recently culminated in global actions and targets. This fight has been a long time coming; it is no wonder that global policies have been set in place to rapidly transform industries in the coming years in an attempt to slow down the climate change clock.

Specifically, the importance of sustainable transport has been highlighted in the United Nations' 2030 Agenda for Sustainable Development. The transport sector is responsible for approximately a quarter of energy-related global greenhouse gas emissions. This becomes even more alarming when we consider how transport has largely been reliant on steadily depleting fossil fuels, and how traffic is projected to increase in the following years. It is no wonder that countries are in the process of finding environmentally friendly alternatives for ICE vehicles.

While sustainable transport can be achieved through a myriad of policies, one of the existing solutions is the move towards EVs and reducing our reliance on ICE vehicles. For Sinagapore, road transportation contributes to approximately 15% of our national CO2 emissions, so reducing reliance on fossil fuels and switching to electricity would aid our goals of decarbonisation. A closer examination on technology landscape and environmental impact of Electric Vehicles will be included in an upcoming article in the series.

2. PASSENGER CARS – CURRENT TAX STRUCTURE

Given our dense population, passenger cars are taxed heavily in Singapore to reduce road congestion. In order to understand government policies towards green cars and incentives towards EV adoption, it is essential to get a picture of current price build-up of passenger cars in Singapore.

For a mass-market petrol SUV such as MG HS, the Open Market Value contributes to only 14% of the retail price, whereas 63% is contributed by COE, ARF, GST & Excise Duty. Vehicles in Singapore are heavily taxed to manage the car population.

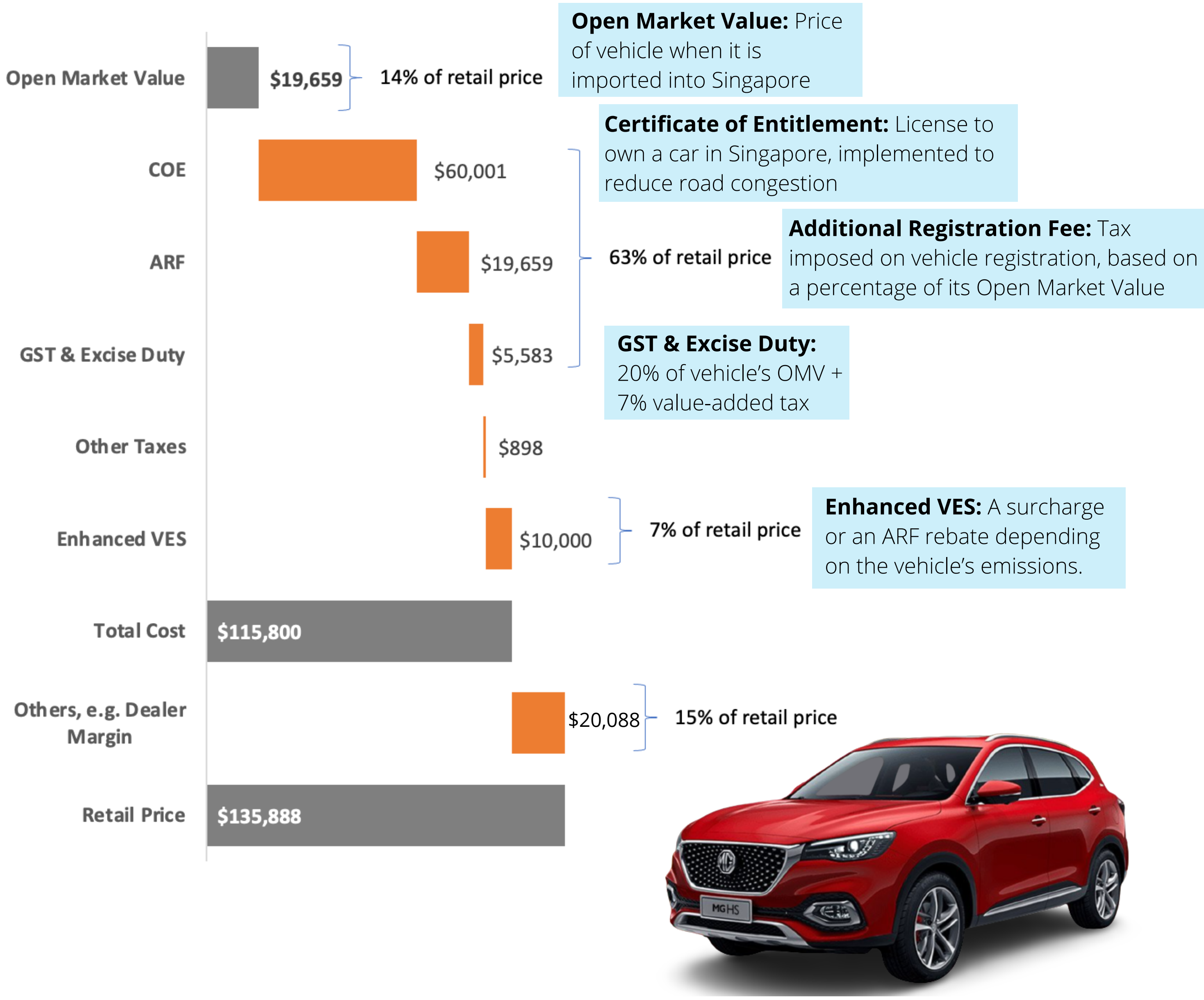


Figure 1: Estimated price of MG HS[1]

[1] Values are based off OneMotoring data and are accurate as of date of publication. Image credit to MG Singapore.

3. GOVERNMENT POLICIES AND IMPACT ON EV ADOPTION

The plan to phase out ICE vehicles by 2040 and to have all vehicles run on clean energy was first announced in Budget 2020, with no diesel cars and taxis to be registered from 2025. To aid this transition, numerous government policies have been implemented to encourage consumer adoption of EVs.

3.1 CURRENT REBATES ON ELECTRIC VEHICLES

The government has rolled out a few policies to encourage EV adoption by helping it achieve price similarity with ICE vehicles. This includes the EV Early Adoption Initiative (EEAI) and the Enhanced Vehicular Emissions Scheme (Enhanced VES).

Policy	Description	Duration
EV Early Adoption Initiative (EEAI)	Owners who register fully electric cars will receive a rebate of 45% off the Additional Registration Fees (ARF), capped at $20,000. This will lower the upfront cost of an EV by an average of 11%.	1 January 2021 – 31 December 2023
Enhanced Vehicular Emissions Scheme (Enhanced VES)	Vehicles enjoy a rebate or surcharge depending on the emissions of their vehicle. This is meant to encourage consumers to buy less pollutive vehicles.	1 January 2021 – 31 December 2022
Lowering ARF Floor to $0	The EEAI and the enhanced VES provide a combined rebate up to $45,000, subject to a minimum ARF of $5,000. ARF will be lowered from $5,000 to $0, for fully electric cars and taxis registered from 1 January 2022 to 31 December 2023.	1 January 2022 – 31 December 2023
Revised Road Tax Schedule	Revised road tax schedule for all newly registered electric cars to better reflects vehicle efficiency. Ensures electric and ICE cars of similar makes and luxury level pay similar road tax.	From 1 January 2022

Figure 2: Policies to help EVs achieve price similarity with EVs [2]

[2] Based on LTA's press releases. Does not include the annual flat road tax that EV owners have to pay.

Comparing the MG ZS EV (the EV equivalent) to the MG HS provides us a clear view of how these rebates are helping in achieving price parity between ICE and EVs.

Policy	 MG ZS EV	 MG HS	Percentage Difference
OMV	+ $32,739	+ $19,659	+ 67%
Registration Fee	+ $220	+ $220	+ 0%
COE	+ $60,001	+ $60,001	+ 0%
Road Tax [3] (per year)	+ $918.85	+ $678.38	+ 35%
Annual Additional Flat Component	+ $200 (for the year 2021)	NA	
ARF	+ $37,835	+ $19,659	+ 92%
GST & Excise Duty	+ $9,298	+ $5,583	+ 67%
EEAI	- $7,835	NA	
Enhanced VES	- $25,000	+ $10,000	+ 350%
Total Cost	$105,626.65	$115,800.30	- 8.8%
Suggested Retail Price	$135,888 (with charger)	$135,888	+ 0%

Figure 3: Price comparison between MG ZS EV and MG HS [4]

As seen, with the EEAI and Enhanced VES, the retail price of the MG ZS EV and the HS are the same. Without such government fiscal aid, the retail price of the EV variant would be $168,723, a 24% increase from its current subsidised price.

[3] Based on new road tax treatment (which will be implemented from January 2022).
[4] Values are based off OneMotoring data and MG pricelist, and are accurate as of date of publication

Industry experts such as McKinsey and IHS Markit stated that, with factors such as falling battery costs and improving battery technology, EV prices are expected to fall in China and Europe in the coming years.

Once price parity is reached (estimated to be around 2027), it is very likely for the market to tip in favour of EVs, and consumer demand for EVs will grow.

Countries that are currently pushing for EV adoption will likely experience price parity around a similar timeframe, or during the 2030s. This timeline applies to Singapore, where price parity remains promising with our push to increase adoption of EVs.

A comparison of long-term costs of refuelling or charging the 2 MG vehicles further supports the case for EV adoption in the future.

	 MG ZS EV	 MG HS	Percentage Difference (EV against ICE)
Average Annual Mileage [5]	17,500km	17,500km	NA
Average Annual Cost of Charging / Petrol	$0.55/kwH	$2.36/litre	NA
Total Cost	$14,148.75	$25,193.00	- 44%

Figure 4: Price comparison between annual costs of charging / refuelling MG ZS EV vs MG HS [6]

Although EVs have yet to reach price parity with ICE vehicles in general, the long-term costs of owning the former would be cheaper than that of owning the latter. In addition to lower refuelling costs, since EVs do not have an internal combustion engine, there will be lower maintenance and service costs in comparison to that of an ICE vehicle.

[5] Based on Data.gov.sg

[6] Values are based off OneMotoring data, and are accurate as of date of publication

3.2 CURRENT ROAD TAX STRUCTURE ON EVS

Did you know that fuel excise duties add up to approximately $1 billion of government revenue?[7] To account for the drop in government revenue since EVs are not subject to fuel excise duties, the government has implemented a new tax structures on EVs.

Road tax has been revised by LTA to apply to all new EVs registered from January 2021 onwards, in which EVs are taxed according to their power rating. This is a short-term measure; LTA has acknowledged that this might change in the future, possibly to distance-based or utility-based charging to be fairer to the consumers. If we make a large-scale shift to EVs, taxes should ideally be based on asset utilisation instead of asset ownership. In a market dominated by premium cars, imposing a high ownership tax on EVs with higher power ratings can potentially discourage adoption.

Existing Road Tax Treatment

Power Rating (kW)	Current 6-Monthly Road Tax Formula
PR ≤ 7.5	S$200 x 0.782
7.5 <PR ≤ 30	[S$200 + S$2(PR - 7.5)] x 0.782
30 < PR ≤ 90	[S$250 + S$3.75(PR - 30)] x 0.782
90 < PR ≤ 230	[S$475 + S$7.50(PR - 90)] x 0.782
PR > 230	[S$1,525 + S$10(PR - 230)] x 0.782

New Road Tax Treatment (from 1 Jan 2022)

Power Rating (kW)	New 6-Monthly Road Tax Formula
PR ≤ 7.5	S$200 x 0.782
7.5 < PR ≤ 30	[S$200 + S$2(PR - 7.5)] x 0.782
30 < PR ≤ 230	[S$250 + S$3.75(PR - 30)] x 0.782
PR > 230	[S$1,525 + S$10(PR - 230)] x 0.782

Figure 5: Revised road tax schedule, credit to LTA Singapore

Furthermore, EVs will be taxed a flat component rate that will increase to $700 from this year.

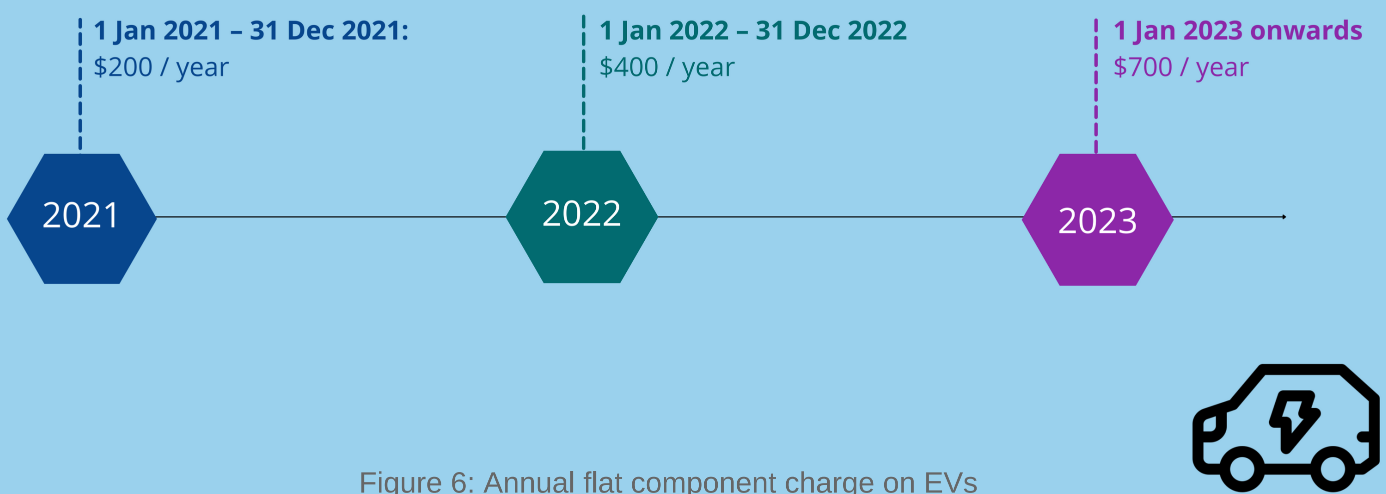


Figure 6: Annual flat component charge on EVs

Despite the tax imposition on EVs, we can expect the cost of owning an EV to be comparable, if not lower, than that of owning an ICE vehicle in the long-run

[7] According to Straits Times Article *Singapore Budget 2020: Push to promote electric vehicles in move to phase out petrol and diesel vehicles* published 18 February 2020

3.3 RELATED TRANSPORT POLICIES

In addition to fiscal incentives, the government has also implemented other policies to cope with the expected growth in EV population and to reduce our transport carbon emission.

3.3.1 EXPANSION OF CHARGING INFRASTRUCTURE

The government is also looking to improve the accessibility of charging infrastructure island wide, with the Singapore Green Plan goal of building 60,000 charging points by 2030. 40,000 charging points will be allocated to public carparks and 20,000 charging points will be allocated to private carparks. This is a significant increase from the current number of 1,900 EV charging points in Singapore.[8]

3.3.2 8 EV-READY TOWNS BY 2025

The Housing Development Board (HDB) carparks in 8 towns (Ang Mo Kio, Bedok, Chua Chu Kang, Jurong West, Punggol, Queenstown, Sembawang and the upcoming Tengah town) will have charging points for EVs by 2025. These towns have been selected based on their high concentration of carparks with existing electrical capacity to support the increase in charging infrastructure, and are also spread across Singapore (picture below).

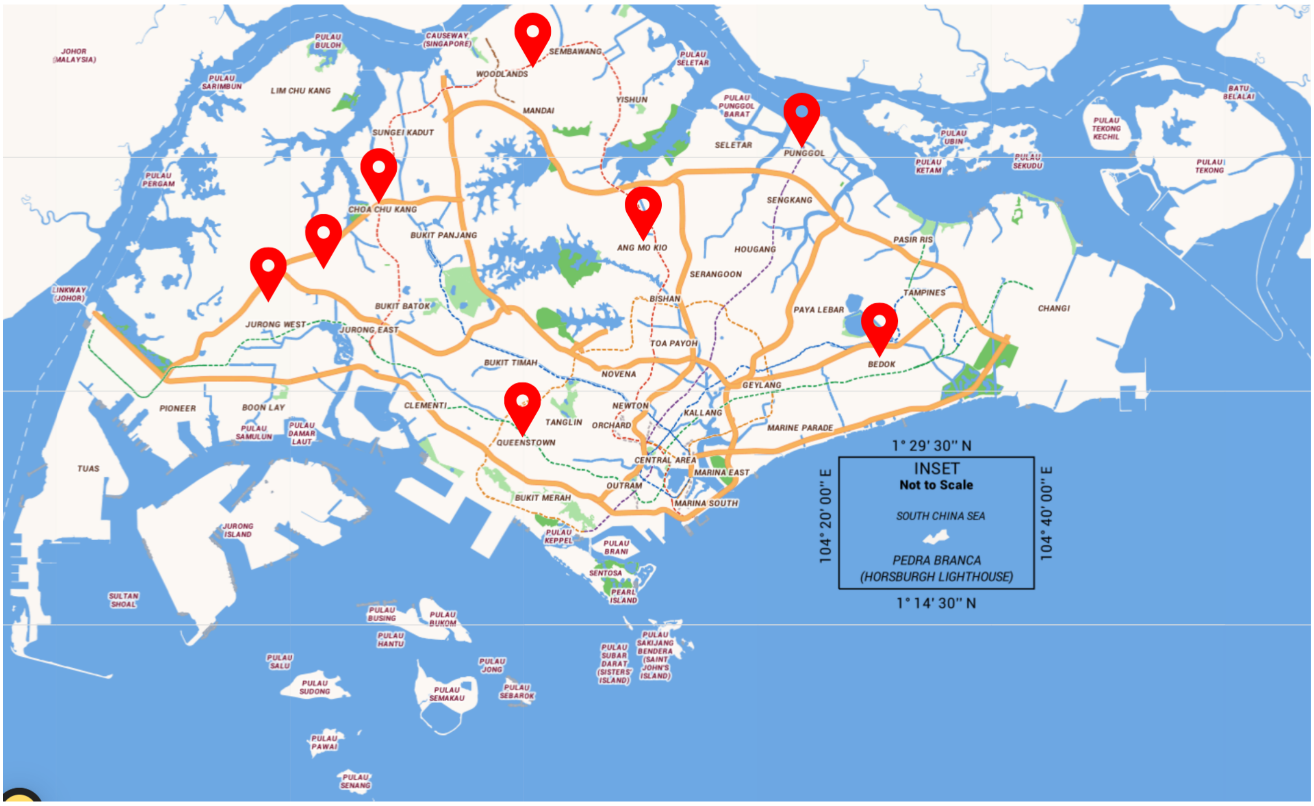


Figure 7: Map of EV-Ready HDB Towns, map credits to OneMap.gov.sg

LTA also plans to increase the number and accessibility of charging infrastructure in all towns by the 2030s.[9]

8 According to written Parliament reply by then-Minister of Transport Ong Ye Kung, published 1 Feb 2021

9 According to LTA Factsheet, published 4 March 2021

3.3.3 PUBLIC TRANSPORT CHANGES

The LTA Land Transport Masterplan 2040 Report has announced its goal of having a public bus fleet that runs entirely on cleaner energy by 2040, i.e. using electric or hybrid vehicles. Currently, our public train system is fully electrified.

3.3.4 TAXI FLEET CHANGES

From 2030, all new taxi registrations have to be models that run on cleaner energy i.e. hybrids, EVs or fuel cell vehicles. Currently, about 60% of our taxis are already petrol-hybrids.[10] Singapore's car fleet operators are committed to 100% cleaner energy fleets by 2040, and have been increasing the number of green vehicles in their fleet.

3.3.5 COE AND ITS IMPACT ON EV ADOPTION

There has been ongoing debate as to whether our goals for road electrification are below expectations, since countries such as Norway and the Netherlands are phasing out both ICE vehicles and hybrids by 2030.

Our move towards phasing out ICE vehicles and hybrids may be impeded by our COE (Certificate of Entitlement) policy, a licence quota that limits the number of people who can own and use a car in Singapore. This was implemented to reduce road congestion due to our high-density population. The COE is here to stay; its intent is to manage car population and road congestion in Singapore, and is independent of the vehicle propellant types. The COE licence lasts for 10 years, as such, adopting greener vehicles might take more time for Singapore.

Then-Transport Minister Ong Ye Kung anticipates that we will have a vehicle fleet that runs on cleaner energy within 2 cycles of COE lifespan. In the meantime, focus is placed on electrifying public transport while making public transport more accessible to encourage usage.

Furthermore, with COE and other car taxes comprising a significant portion of the price of a car in Singapore (as seen in Figure 1), even when EVs reach price parity with ICE vehicles (approximately 2025 to 2027), fiscal incentives are still needed to increase EV adoption. Hence, EV adoption may be slower in Singapore in comparison to other countries due to COE and high vehicle taxes.

[10] According to speech by then-Minister of Transport Ong Ye Kung, on 4 March 2021 at Ministry of Sustainability and the Environment's COS Debates.

4. IMPROVING ACCESSIBILITY OF PUBLIC TRANSPORT

The government is not placing all their eggs in the EV basket alone. Beyond reducing transport carbon emissions via transport electrification, they are also looking at encouraging utilisation of public transport.

Then-Transport Minister Ong Ye Kung (now Minister for Health) said that while EVs are the cleaner alternative to ICE vehicles, using an EV does not necessarily mean you are no longer harming the environment, “just that you are polluting less”. Hence, there is a preference for driving public transportation usage as it is the most sustainable form of transport.

4.1 LTA LAND TRANSPORT MASTER PLAN 2040: 20-MINUTE TOWNS AND A 45-MINUTE CITY

LTA has announced their 2040 goals of transforming Singapore into (i) 20-minute towns and (ii) a 45-minute city in efforts to improve the accessibility of public transport. Ideally, Singaporeans would prefer to walk, cycle, or take public transport, with 9 in 10 of peak-period travels consisting of these transportation methods. “20-minute towns” refers to how journeys within the nearest neighbourhood can be completed within 20 minutes via walking, cycling, or public transport. A "45-minute city" refers to how 9 in 10 peak-period door-to-door journeys via walking, cycling or public transport would take less than 45 minutes.

Figure 8: 20-min town and 45-min city[11]

11 Image credit to LTA.

4.2 SINGAPORE TRANSPORT MOBILITY 2050

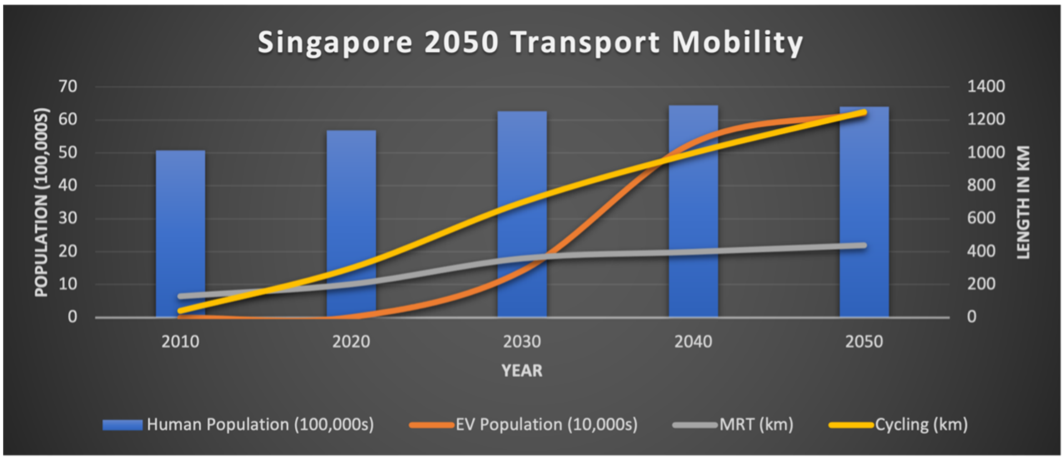
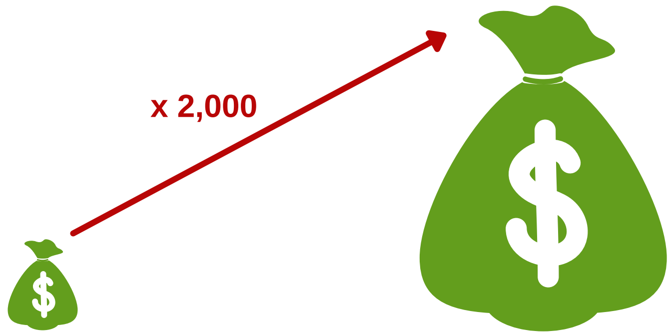


Figure 9: Comparison of human population against future transportation goals[12]

Aligned to its goals of sustainable and decarbonised transportation, Singapore MRT railway length and cycling routes are expected to grow, as seen in the figure above, in the coming decades to become a “car-lite” nation.

Future projections for transportation modes reflects the desire to create a social preference for public transport over private transportation.

Additionally, the government is spending $60 billion over the next decade on expanding our public transport system, and $30 million over the next 5 years on research into electric vehicles and financing its fiscal incentives. The budget for expansion of public transportation is 2,000 times larger than that of the EV budget; even if the EV budget was doubled to account for how much the government might spend in a decade, the public transport expansion budget would still be 1,000 times larger than the EV budget.



The government’s priority is clear; while EVs are the greener form of private transportation, ultimately, pedestrianising the city and encouraging usage of public transport would be less taxing on the environment

[12] According to Differential Asia's projections.

In addition to building 20-minute towns and a 45-minute city, with a denser rail network and longer cycling routes, the goal is clear; we are moving towards being a car-lite society, where public transport or walking is the preferred mode of transport over private transport. The goal is to achieve a peak hour mode share of 75% for public transport by 2030, an increase from 64% in 2013. This reduces the overall carbon footprint of our private transportation on the environment, and also reduces other harmful environmental impacts such as air pollution.

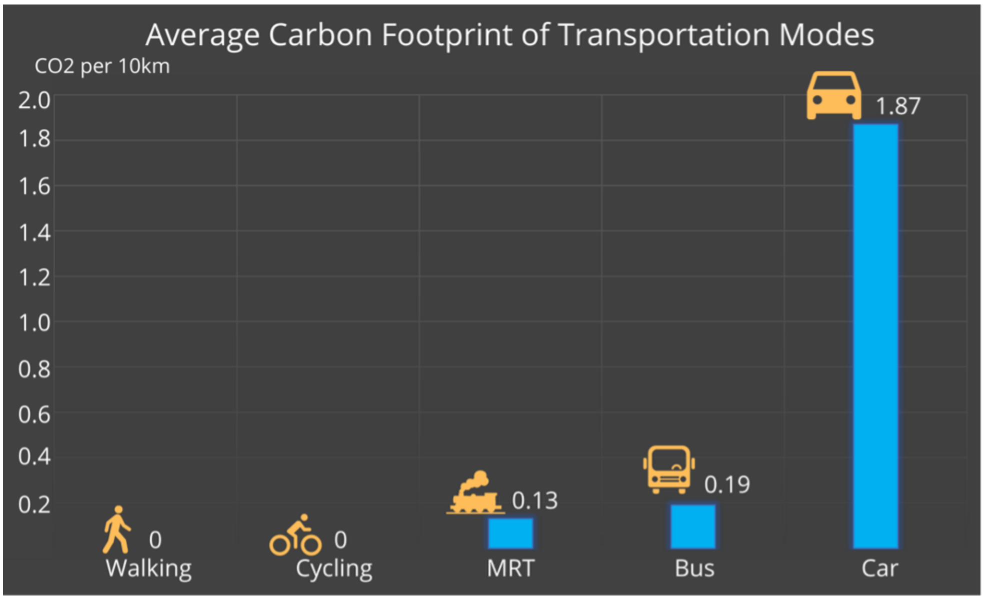


Figure 10: Comparison of average carbon footprint of transportation modes[13]

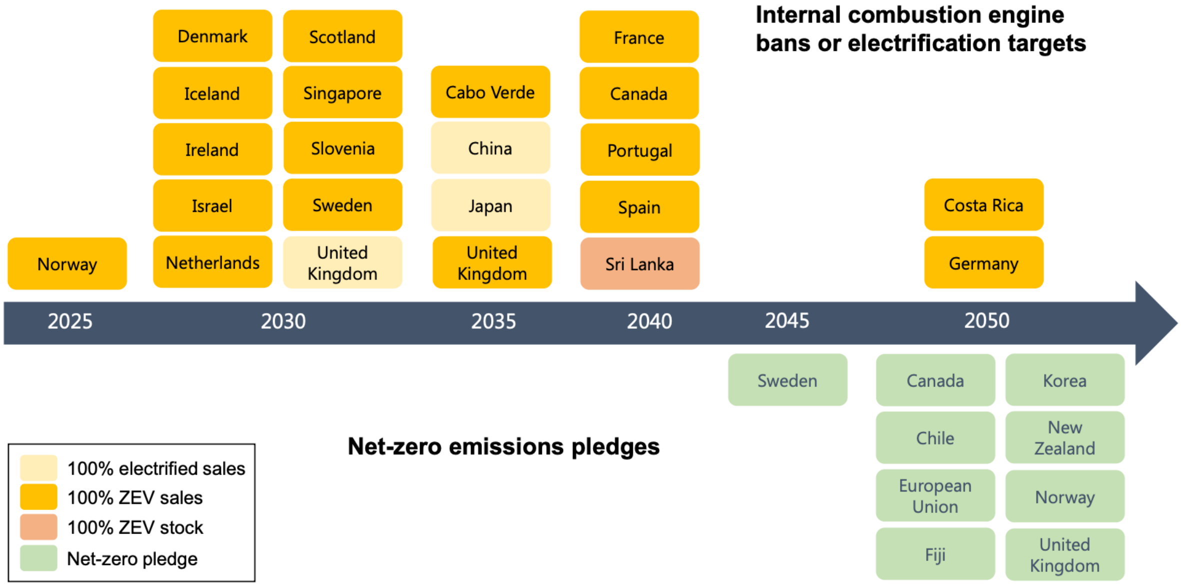
As seen in the figure above, travelling by car produces the largest carbon footprint. Hence, encouraging public transport by making it more accessible would be more environmentally friendly in comparison to merely encouraging the adoption of EVs. A detailed analysis into how green EVs are exactly will be included in the next article.

[13] Assuming an average loading of 80 passengers per bus and 1,100 per train. Based on Sustainable Singapore Blueprint 2015

5. GLOBAL EV PROGRESS

With several countries moving towards adoption of EVs, we can look at their progress to understand this global trend and to better gauge Singapore's progress.

5.1 ELECTRIFICATION TARGETS / BANS ON ICE VEHICLES



Notes: Only countries that have either an ICE ban or electrification target or with net-zero emissions in law or proposed legislation have been included. Those with net-zero emissions policy documents only, e.g. Japan and China, have not been included. European Union refers to the collective pledge of the 27 member states. Some individual countries also have net-zero emissions pledges either in law or proposed legislation (Denmark, France, Germany, Hungary, Ireland, Luxembourg, Slovenia, Spain, Sweden and the Netherlands). The targets reflect the status as of 20 April 2021. Electrified vehicles here include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), fuel cell electric vehicles (FCEVs) and hybrid electric vehicles (HEVs), depending on the definitions of each country. ZEV = zero-emission vehicle (BEVs, PHEVs and FCEVs)

Figure 11: Global electrification goals
Source: IEA Global EV Outlook 2021

While the US does not have a clearly articulated goal to phase out ICE cars, it is worth noting that certain states such as California are strongly committed to electrify their transportation. The current Biden administration is also facing pressure from governors of 12 states to ensure that all cars sold from 2035 are zero-emission, although there has been no official national policy introduced as of publication date.

Malaysia also has no official policy to phase-out ICE vehicles.

5.2 CHARGING INFRASTRUCTURE COMPARISONS

To better gauge Singapore's charging infrastructure progress, we compare her goals to Norway's and South Korea's, both bellwether countries for EV adoption.

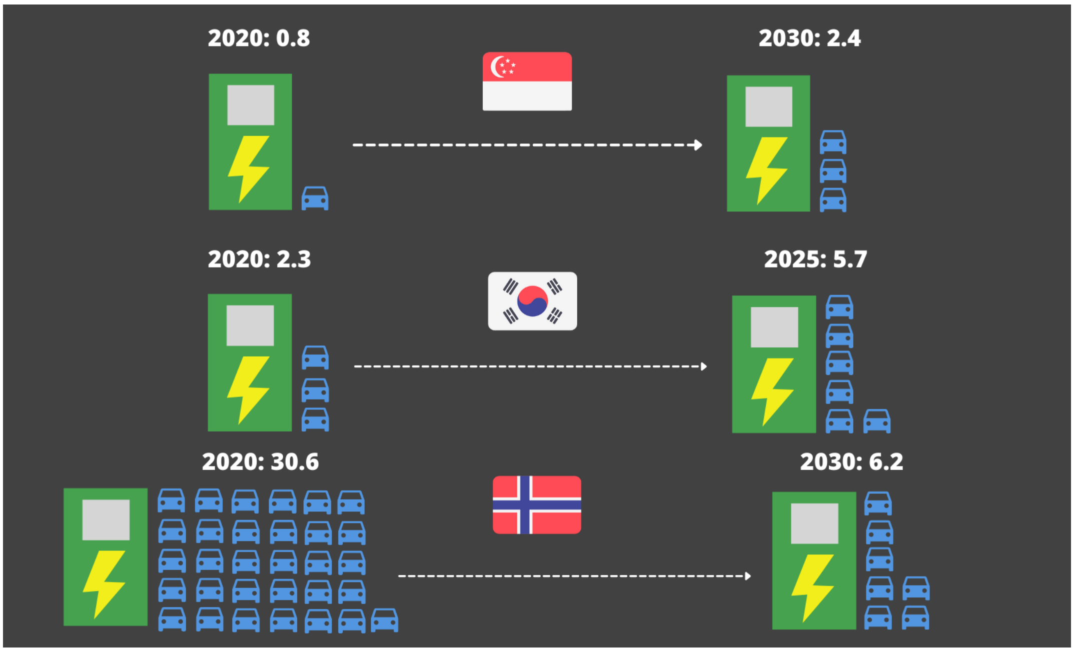


Figure 12: Ratio of number of EVs per charging point (Singapore vs South Korea vs Norway)[14]

With a similarly small and dense population of 5.39 million, and similar goals of pedestrianising their states,[15] Norway is frequently used for comparison with Singapore. Norway is the first country where EV sales have overtaken that of other fuel types; as of 2020, battery electric vehicles made up 54.3% of all new cars sold in the country. Furthermore, Norway is expected to drastically improve the accessibility of their charging infrastructure by 2030; from a ratio of 30.6 EVs to 1 charging point, they will improve to 6.2 EVs per charging point in a decade. Hence, Norway is frequently used as the basis of comparison for several countries.

South Korea is also expected to enjoy a low density of EVs per charging point; nonetheless, since there is no projected figure for 2030, it is hard to estimate how they would perform then, though we can assume the ratio of EVs per charging point would still remain relatively low.

As seen in the figure above, Singapore's density of EVs per charging point will increase, just like South Korea's; both are projected to increase approximately threefold. Although this might not seem to bode well, given that it implies more cars will be using the same charger, we still need to take into account that this is due to projected increase in charging infrastructure and EV population. Nonetheless, beyond 2030, we need to keep a close eye on EV adoption and accessibility of EV chargers to see if we should be building charging infrastructures at a faster rate to keep up with growing demand for EVs as ICE vehicles are phased out by 2040.

[14] South Korea's projections are until the year 2025. Figures have been rounded to 1 decimal place, but cars depicted are rounded to nearest number for clarity in presentation.

[15] Orchard Road for Singapore

6. CONCLUSION

As seen, there are several steps in place to ensure affordability of EVs. Although EVs are currently taxed according to their power rating, and users have to pay an annual tax, the rebates that one enjoys from purchasing an electric car does help it to achieve price similarity with ICE vehicles. Furthermore, with the promise to increase the number of charging points, the appeal of an EV is now undeniable. However, there may still be concerns from consumers regarding its accessibility or charging time, or even the state of charging infrastructure in Malaysia (for those who frequently travel between the two).

Government incentives are critical in fuelling early adoption of EVs and signalling to automakers that the will to electrify is there. However, consumer demand for vehicles is price elastic; they will buy the vehicle that is most worth it for its price. Hence, the onus also lies on suppliers and OEMs to continue to drive price parity of EVs and to address user concerns (range anxiety, charging time, reliability, etc.).

Globally, there is strong political will to commit to combating climate change, sparking policy changes that creates a conducive environment for manufacturers to follow the trend. COVID-19 is not the only watershed event for the automotive industry; to remain relevant, manufacturers have to adapt to global preferences to survive. In recognition of this pivotal shift towards greener vehicles, we can also expect the number of EV models available to increase as manufacturers are forced to compete in an arms race to gain market power as preference for ICE vehicles decreases.

In the next chapter, we will be looking at the technology and environment pillar to analyse how environmentally friendly EVs are, and the ongoing EV arms race.

[37] According to IEA EV Global Outlook 2021

REFERENCES

Aldred J. & Goodchild L. (2007, October 12). *Timeline: Al Gore.* The Guardian. https://www.theguardian.com/environment/2007/oct/12/climatechange1

Australian Renewable Energy Agency. (2018, May). *Australian Electric Vehicle Market Study.*

Baik, Y., Hensley, R., Hertzke, P. & Knupfer, S. (2019, March 8). *Making electric vehicles profitable.* McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/making-electric-vehicles-profitable

Bloomberg New Energy Finance. (2021, May). *Study: Hitting the EV Inflection Point.* https://www.transportenvironment.org/publications/hitting-ev-inflection-point

Business Times. (2019, October 16). *South Korea speeds up plans for autonomous, electric and flying cars.* Business Times. https://www.businesstimes.com.sg/transport/south-korea-speeds-up-plans-for-autonomous-electric-and-flying-cars

Data.gov.sg. (n.d.). *Annual Mileage for Private Motor Vehicles*. https://data.gov.sg/dataset/annual-mileage-for-private-motor-vehicles?view_id=fea21992-54d7-4fbc-a8ab-ec4c8b6b4e94&resource_id=7a913480-0de4-45b8-b922-18166d10d7db

Data.gov.sg. (n.d.). *Annual Motor Vehicle Population by Vehicle Quota Categories*. https://data.gov.sg/dataset/annual-motor-vehicle-population-by-vehicle-quota-category?view_id=b3321e3c-9134-46d8-8e92-f68acef38e35&resource_id=93430d5e-903c-4402-8343-8a260f4f4354

Data.gov.sg. (n.d.) *Rail Length (km) At End-of-Year.* https://data.gov.sg/dataset/rail-length?view_id=4209993c-5e61-4c1f-8b1a-e6903eb941b1&resource_id=087f64e3-9f69-46de-8d70-6d96676b1bfa

Data.gov.sg. (n.d.). *Singapore Residents by Age Group, Ethnic Group and Gender, End June, Annual*. https://data.gov.sg/dataset/resident-population-by-ethnicity-gender-and-age-group?view_id=8ff89d3f-48c8-46e4-8a4d-a8b9f152976f&resource_id=f9dbfc75-a2dc-42af-9f50-425e4107ae84

Electric Vehicle Association of Singapore. (2021, March). *Singapore Electric Vehicle Guide 2021.* https://www.evas.org.sg/#ev-guide-2021

Euromonitor International. (n.d.). *China Country Factfile.* https://www.euromonitor.com/china/country-factfile

Euromonitor International. (n.d.). *Malaysia Country Factfile*. https://www.euromonitor.com/malaysia/country-factfile

Finlay, S. (2021, January 29). *Automotive R&D Budgets Take a Hit.* Wards Auto. https://www.wardsauto.com/industry-news/automotive-rd-budgets-take-hit

Franke, A. (2020, November 17). *German EV chargers up 19% to 33,000 as utility / auto lobbies differ over rollout. S&P Global*. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/111720-german-ev-chargers-up-19-to-33000-as-utilityauto-lobbies-differ-over-rollout

REFERENCES

Global Petrol Prices. (2021, June 7). *Gasoline prices around the world, 07-Jun-2021*. https://www.globalpetrolprices.com/gasoline_prices/#hl147

IHS Markit. (2021, April). *Pivoting to an electrified future.*

International Energy Agency. (2020). Global EV Outlook 2020, IEA, Paris. https://www.iea.org/reports/global-ev-outlook-2020

International Energy Agency. (2020). Spending on EV purchases, 2010-2019, IEA, Paris https://www.iea.org/data-and-statistics/charts/spending-on-ev-purchases-2010-2019

International Energy Agency. (2021). Global EV Outlook 2021, IEA, Paris. https://www.iea.org/reports/global-ev-outlook-2021

Kok, Y. (2021, March 12). *Electric vehicles less pollutive, but not the most sustainable mode of transport: Ong Ye Kung.* The Straits Times. https://www.straitstimes.com/singapore/electric-vehicles-less-pollutive-but-not-the-most-sustainable-mode-of-transport-ong-ye

Kollewe, J. (2021, May 21). *6.5m households in UK plan to buy an electric car by 2030.* The Guardian. https://www.theguardian.com/business/2021/may/21/65m-households-uk-electric-car

Lam, F. (2020, February 16). *Budget 2021: $30m for EV initiatives; electric cars' road taxes to be adjusted.* The Business Times. https://www.businesstimes.com.sg/government-economy/singapore-budget-2021/budget-2021-s30m-for-ev-initiatives-electric-cars-road

Lam, F. (2020, February 18). *Budget 2020: Govt aims to phase out all vehicles with internal combustion engines by 2040.* The Business Times. https://www.businesstimes.com.sg/government-economy/singapore-budget-2020/budget-2020-govt-aims-to-phase-out-all-vehicles-with

Land Transport Authority. (2020). Annual Vehicle Statistics 2020.

Land Transport Authority. (2020, February 18). *Factsheet: Accelerating Nationwide Deployment of Electric Vehicle Charging Points*. https://www.lta.gov.sg/content/ltagov/en/newsroom/2021/3/news-release/Accelerating_nationwide_deployment_of_electric_vehicle_charging_points.html

Land Transport Authority. (2020, February 18). *Supporting Cleaner and Greener Vehicles for a Sustainable Land Transport Sector*. https://www.lta.gov.sg/content/ltagov/en/newsroom/2020/2/news-releases/Supporting_cleaner_and_greener_vehicles.html

Land Transport Authority. (2020, June). Land Transport Master Plan 2040.

Land Transport Authority. (2021, March 4). *Factsheet: Accelerating Nationwide Deployment of Electric Vehicle Charging Points*. https://www.lta.gov.sg/content/ltagov/en/newsroom/2021/3/news-release/Accelerating_nationwide_deployment_of_electric_vehicle_charging_points.html#:~:text=Factsheet%3A%20Accelerating%20Nationwide%20Deployment%20of%20Electric%20Vehicle%20Charging%20Points,-News%20Releases%2004&text=The%20Government%20targets%20to%20deploy,and%2020%2C000%20in%20private%20premises.

REFERENCES

Land Transport Authority. (2021, March 4). *Factsheet: Encouraging the Adoption of Electric Cars for a More Sustainable Land Transport Sector*. https://www.lta.gov.sg/content/ltagov/en/newsroom/2021/3/news-release/Encouraging_the_adoption_of_electric_cars.html

Lienert P. (2018). *Global carmakers to invest in at least $90 billion in electric vehicles.* Reuters. https://www.reuters.com/article/us-autoshow-detroit-electric-idUSKBN1F42NW

Lienert P., Shirouzu N., Taylor E. (2019). *Exclusive: VW, China spearhead $300 billion global drive to electrify cars.* Reuters. https://www.reuters.com/article/us-autoshow-detroit-electric-exclusive-idUSKCN1P40G6

Lewis, M. (2020, September 18). *South Korea to boost EV numbers to 1.13 million by 2025*. Electrek.co. https://electrek.co/2020/09/08/south-korea-to-boost-ev-numbers-to-1-13-million-by-2025/

Makortoff, K. & Ambrose, J. (2021, May 24). *Britain's electric car charging network boosted by £300m funding.* The Guardian. https://www.theguardian.com/environment/2021/may/24/britain-electric-car-charging-network-ofgem-points

McKinsey & Company. (2020, July 17). *McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales*. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-electric-vehicle-index-europe-cushions-a-global-plunge-in-ev-sales#:~:text=EV%20sales%20dropped%20by%2057,that%20were%20about%20to%20expire

McKinsey & Company. (2020, September 16). *Electric mobility after the crisis: Why an auto slowdown won't hurt EV demand.* https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/electric-mobility-after-the-crisis-why-an-auto-slowdown-wont-hurt-ev-demand

Milman, O. (2021, April 30). *Biden faces pressure to drive gasoline and diesel cars out of the US.* The Guardian. https://www.theguardian.com/us-news/2021/apr/30/biden-administration-cars-emissions

Ministry of Transport. (n.d.). *Trains: Expanding our Rail Network*. https://www.mot.gov.sg/About-MOT/Land-Transport/Public-Transport/Trains/#:~:text=Expanding%20Our%20Rail%20Network,reach%20more%20people%20and%20places.

Ministry of the Environment and Water Resources & Ministry of National Development. *Sustainable Singapore Blueprint 2015.* https://www.nccs.gov.sg/docs/default-source/default-document-library/sustainable-singapore-blueprint-2015.pdf

National Development Council. (n.d.). *Population Projections for Taiwan.* https://pop-proj.ndc.gov.tw/main_en/dataSearch6.aspx?uid=78&pid=78

National Environment Agency. (2020, November 12). *Increased Rebates for Cleaner Vehicles Under Enhanced Vehicular Emissions Scheme.* https://www.nea.gov.sg/media/news/news/index/increased-rebates-for-cleaner-vehicles-under-enhanced-vehicular-emissions-scheme

REFERENCES

OneMotoring. (n.d.). *Fuel Cost calculator*. https://vrl.lta.gov.sg/lta/vrl/action/pubfunc?ID=FuelCostCalculator

OneMotoring. (n.d.). *Vehicle Tax Structure*. https://onemotoring.lta.gov.sg/content/onemotoring/home/buying/upfront-vehicle-costs/tax-structure.html

OneMotoring. (2020, April). *Open Market Value (OMV)*. https://onemotoring.lta.gov.sg/content/onemotoring/home/buying/upfront-vehicle-costs/open-market-value--omv-.html?year=2021

OneMotoring. (2021, May). *Cost (S$) For Cars Registered in May 2021.*

SGTrains. (n.d.). Network. https://www.sgtrains.com/network-nsl.html

Statistics Korea. (2015, July 8). *Population Trends and Projections of the World and Korea.*

Statista Research Department. (n.d). *Global automotive research and development expenses 2020.* https://www.statista.com/statistics/373853/global-automotive-research-and-development-spending/

Statista Research Department. (n.d.). *Population in Norway*. https://www.statista.com/statistics/586378/total-population-by-age-group-in-norway/

Statista Research Development. (n.d.). *Population in the United States*. https://www.statista.com/statistics/241488/population-of-the-us-by-sex-and-age/

Tan, C. (2020, February 18). *Singapore Budget 2020: Push to promote electric vehicles in move to phase out petrol and diesel vehicle*. The Straits Times. https://www.straitstimes.com/singapore/transport/singapore-budget-2020-push-to-promote-evs-in-move-to-phase-out-petrol-and-diesel

Tan, C. (2020, August 10). *Cycling path network in Singapore to treble by 2030.* The Straits Times. https://www.straitstimes.com/singapore/transport/cycling-path-network-to-treble-by-2030

Tan, C. (2021, March 5). *Budget debate: No more new diesel cars, taxis in S'pore from 2025.* The Straits Times. https://www.straitstimes.com/singapore/transport/no-more-new-diesel-cars-taxis-from-2025?utm_medium=social&utm_source=telegram&utm_campaign=sttg

Tan, M. (2021, March 4). *No new diesel cars, taxis in Singapore; road taxes for EVs updated: Ong Ye Kung.* The Business Times. https://www.businesstimes.com.sg/government-economy/singapore-budget-2021/no-new-diesel-cars-taxis-in-singapore-road-taxes-for-evs

Tan, J. (2021, April). *These Are The Roadblocks Slowing Down Malaysia In The Global EV Adoption Race.* Vulcan Post. https://vulcanpost.com/738710/malaysia-electric-vehicle-adoption-slow-reasons-challenges/

The Guardian. (2021, January 5). *Electric cars rise to record 54% market share in Norway.* The Guardian. https://www.theguardian.com/environment/2021/jan/05/electric-cars-record-market-share-norway

REFERENCES

United Nations Framework Convention on Climate Change. (n.d.). *What is the Kyoto Protocol?* https://unfccc.int/kyoto_protocol

United Nations. (n.d.) *Sustainable transport*. https://sustainabledevelopment.un.org/topics/sustainabletransport

United Nations. (2016, April 20). *List of Parties that signed the Paris Agreement on 22 April.* https://www.un.org/sustainabledevelopment/blog/2016/04/parisagreementsingatures/

Wong, P. T. (2021, March 1). *A timeline of S'pore's electric vehicle journey so far.* Today Singapore. https://www.todayonline.com/singapore/spores-electric-vehicle-journey-so-far

Yusof, A. (2021, March 14). *Malaysia needs better EV infrastructure to avoid 'anxiety' on road trips, drivers say.* Channel News Asia. https://www.channelnewsasia.com/news/asia/malaysia-singapore-transport-electric-cars-ev-range-anxiety-14381688

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DIFFERENTIAL ASIA PRESENTS

THE ROAD TO ELECTRIC VEHICLES IN SINGAPORE

Part 2: Environment and Technology Landscape

ENVIRONMENT AND TECHNOLOGY

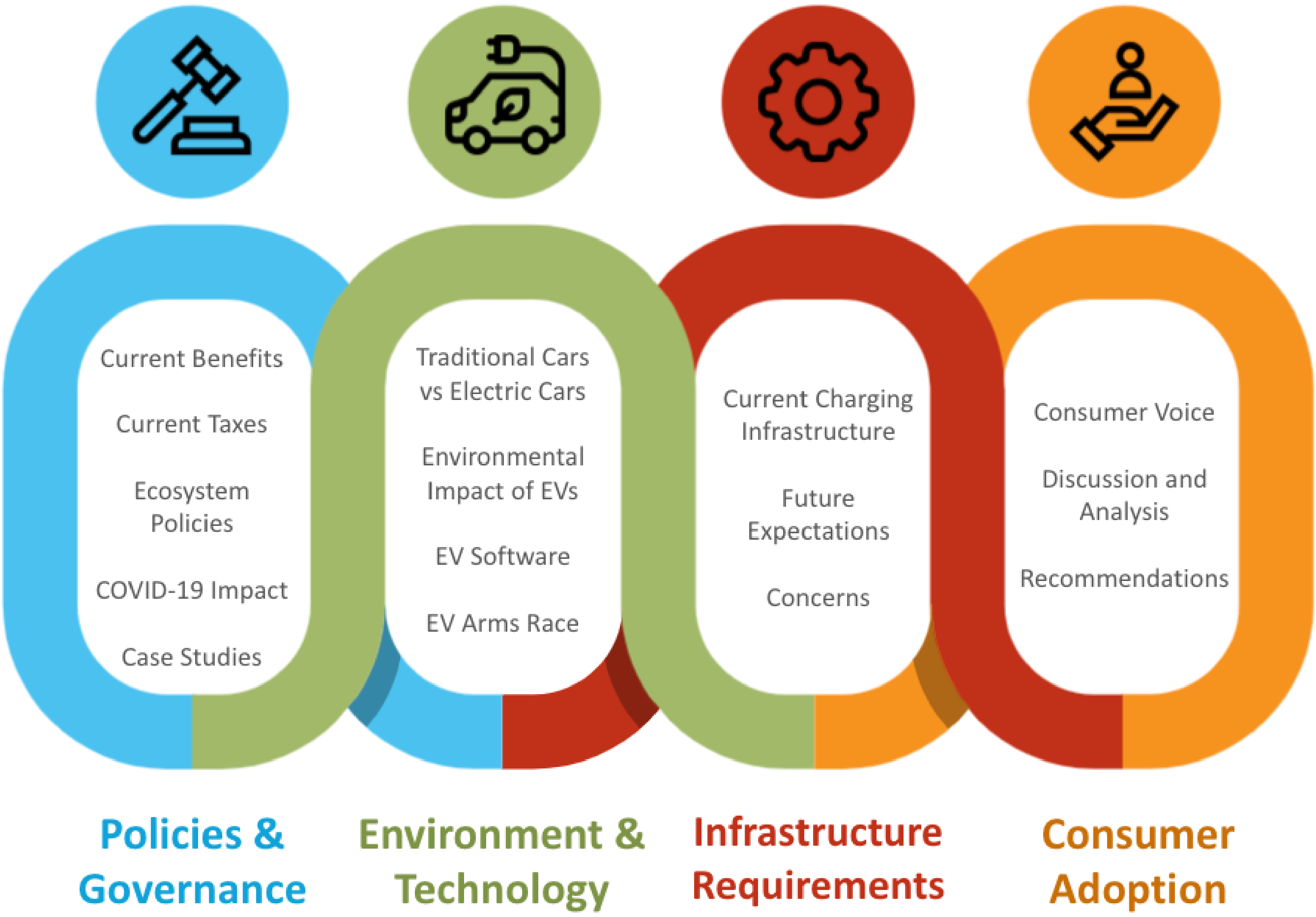
After the previous article's coverage on the global trend towards transport electrification and local policies implemented to encourage adoption of electric vehicles (EVs), in this article, we analyse dimensions related to environment and technology that are critical to EV adoption.

differential

Differential Asia is a leading automotive consulting firm that provides advice and recommendations on concerns such as customer centricity and operational effectiveness.
Recognising the increasing relevance of electric vehicles, we decided to compile an educational report on electric vehicles in Singapore to provide a holistic understanding of the local electric vehicle scene.

OVERVIEW

Differential Asia has written four articles regarding the Singapore EV ecosystem, as seen in the image below.



In this chapter, we look at the technology behind electric vehicles; the differences between them and traditional ICE vehicles (vehicles with internal combustion engines i.e. petrol or diesel vehicles) and their overall impact on the environment. We also look at the technological changes that are expected to transform the automotive industry, and how these changes manifest across vehicular systems and the economy.

CONTENT PAGE

1. COMPARISON BETWEEN ICE AND ELECTRIC VEHICLES

With only 0.2% of cars being fully electric as of May 2021, the goal of phasing out ICE (internal combustion engine) vehicles by 2040 may seem like a distant dream. Understanding the different types of electric vehicles available may aid our willingness to purchase it.

There are four EV technologies available in the automotive industry: 1) battery electric vehicles (BEVs) 2) plug-in hybrid electric vehicles (PHEVs), 3) hybrid electric vehicles (HEVs) and 4) fuel cell electric vehicles (FCEVs).

It is important to note that, among these four types of electric vehicles, only BEVs, PHEVs and FCEVs are zero-emission vehicles; the HEV still has some negative impact on the environment.

The differences between these four technologies are highlighted in the sections below.

1.1 BATTERY ELECTRIC VEHICLES (BEVS)

How it Works

BEVs are fully electric vehicles with no internal combustion engine. It is a type of plug-in electric vehicle that unlike ICE vehicles, does not generate any harmful exhaust emissions.[1] The energy used to run the vehicle comes from the battery pack which is recharged using electricity. Additionally, when braking, the vehicle converts wasted kinetic energy from the wheels to recharge the battery (regenerative braking).

Environmental Impact

While there are no exhaust emissions, it is important to also take into account the source of electricity when charging the vehicle; if electricity is sourced from renewable sources, it is largely environmentally-friendly. However, if electricity is sourced from non-renewable sources, then it is still polluting the environment. In totality, the BEV is greener than the ICE vehicle.

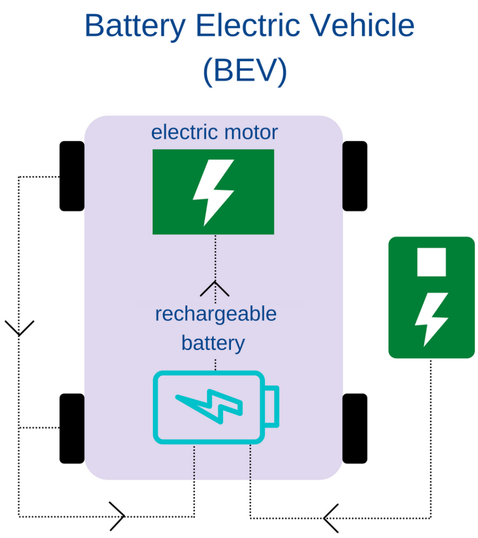


Figure 1: BEV energy flow (left) and examples of BEVs (right)[2]

[1] Pollutants / greenhouse gases in exhaust gases that harm the environment, e.g. carbon dioxide and hydrocarbons
[2] BEV image credits to: Nissan Singapore, Renault Singapore and Tesla Singapore

1.2 PLUG-IN HYBRID ELECTRIC VEHICLES (PHEVS)

How it Works

PHEVs rely on both an ICE engine and an electric motor to drive the car. Similar to regular hybrids, they can recharge their battery through regenerative braking.

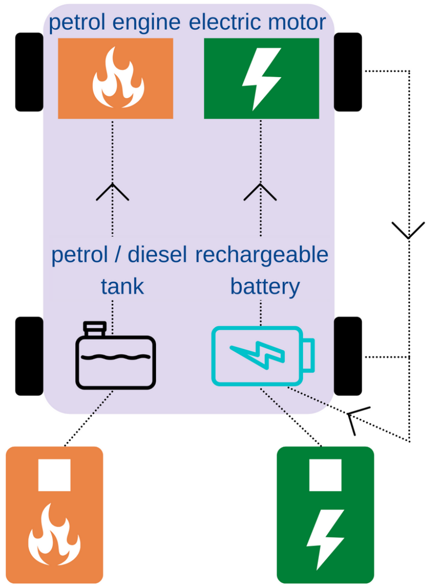
Regular hybrids can be driven for a few kilometres before the ICE engine is turned on. On the other hand, PHEVs can be driven for a higher range, e.g. up to 65km before their ICE engines provide assistance. Once the electric motor is depleted, PHEVs act as regular hybrids and can travel several hundred kilometres on a tank of petrol.

Environmental Impact

Its electric motors make it possible to drive the vehicle in pure-electric mode for a typical distance of 20 to 50km. If the PHEV is always driven in pure-electric mode, It is technically possible for it to run solely on electricity.

Hence, its tailpipe emissions, while lesser than that of an ICE vehicle, is still more than that of a BEV, especially if not driven in pure-electric mode.

Plug-In Hybrid Electric Vehicle (PHEV)



Toyota Prius Prime

Honda Accord

Volvo XC90 Recharge

Figure 2: PHEV structure and examples of PHEVs[3]

[3] BEV Structure by Differential Asia. BEV examples image credit to: Toyota, Honda Singapore and Volvo Singapore

1.3 HYBRID ELECTRIC VEHICLES (HEVS)

How it Works

Unlike PHEVs, a hybrid electric vehicle (HEV) does not have an external plug that allows it to be charged by electricity. Instead, the electric power for the motor is generated from regenerative braking and from the petrol engine.

Its regenerative braking recoups otherwise lost energy in braking to assist the petrol engine during acceleration. In an ICE vehicle, this braking energy is normally lost as heat in the brake pads and rotors.

Environmental Impact

When driven in hybrid mode, hybrids can reduce lifecycle greenhouse gas emissions (such as carbon dioxide) by 15% to 30% in comparison to an ICE equivalent.

When driven in electric-only mode, hybrids produce approximately up to 40% less carbon dioxide than its ICE equivalent.

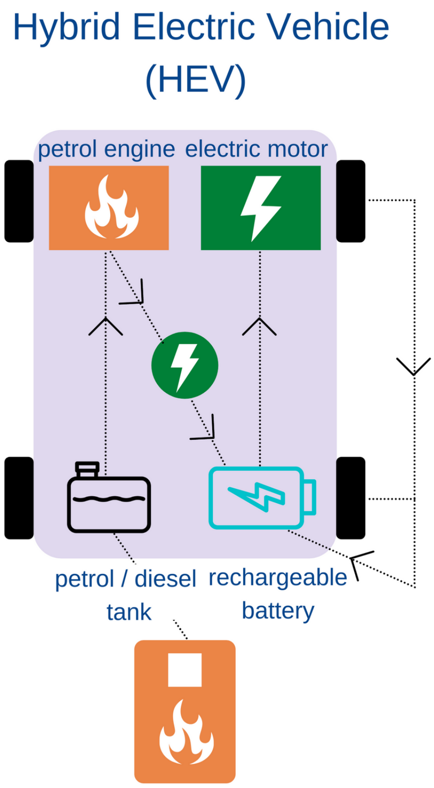


Figure 3: HEV structure and examples of HEVs[4]

[4] HEV Structure by Differential Asia. HEV examples image credit to: MotorTrend, Toyota Singapore and Honda Mall of Georgia

1.4 FUEL CELL ELECTRIC VEHICLES (FCEVS)

How it Works

Similar to EVs, FCEVs use electricity to power an electric motor. However, FCEVs produce electricity using a hydrogen-powered fuel cell that generates electricity through an electrochemical reaction of hydrogen and oxygen that occurs within the vehicle. In contrast, electricity for an EV is generated outside the vehicle and is stored in the battery.

In a FCEV, electricity can come from either the fuel cell or from the battery pack that stores excess electricity and electricity generated by regenerative braking.

Refuelling a FCEV typically takes less than 10 minutes.

Environmental Impact

Similar to the BEV, the FCEV has no tailpipe emissions, and can only be considered truly green if green hydrogen is used.

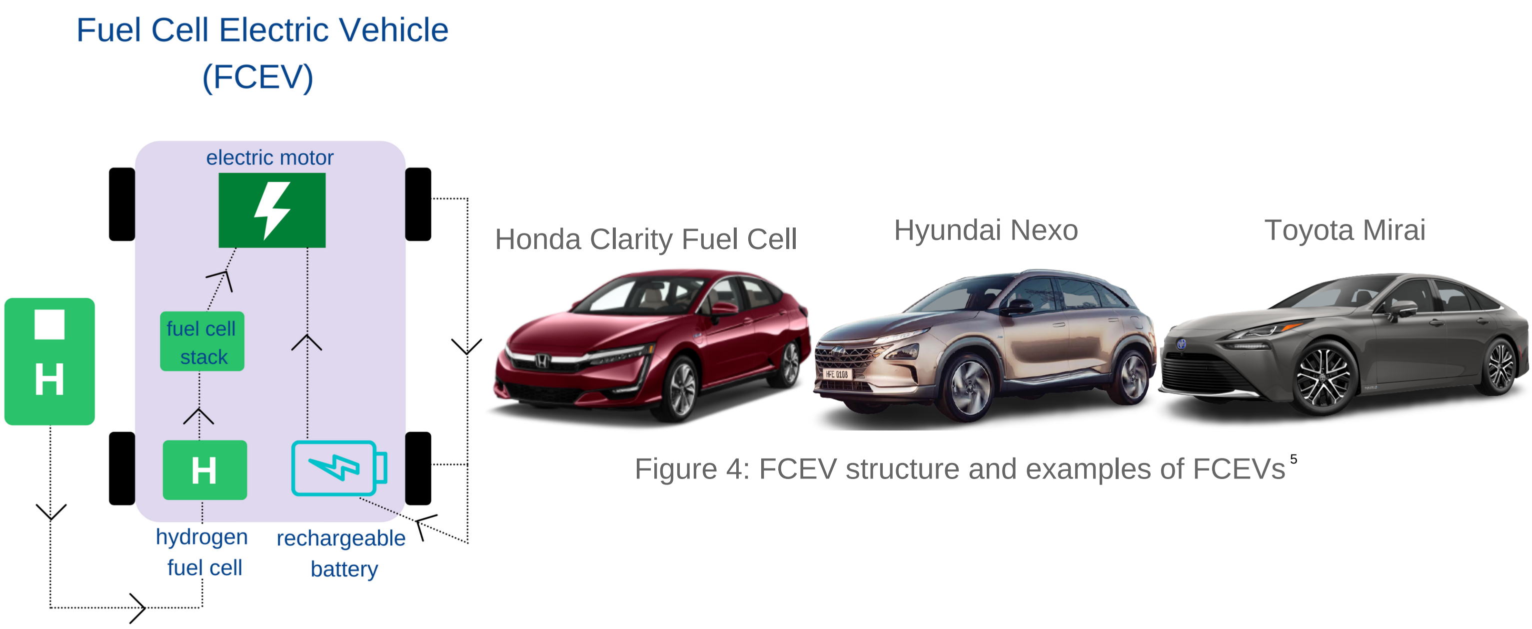


Figure 4: FCEV structure and examples of FCEVs[5]

[5] FCEV Structure by Differential Asia. FCEV examples image credits to: MotorTrend, Hyundai and Toyota

1.4.1. WHY DON'T WE USE FUEL CELL ELECTRIC VEHICLES?

Given advantages such as shorter refuelling time and offering a larger range on a single refuelling, one might wonder why Singapore does not encourage adoption of FCEVs instead of BEVs, PHEVs or hybrids. Currently, Singapore does not have any FCEVs on the road, and it is estimated to take up to 20 years for FCEVs to be used on a large scale in Singapore.

Globally, there are only 30,000 FCEVs on the road as of May 2021 — approximately less than 0.4% of the global fleet.[6] This low use of FCEVS, both local and global, can be attributed to various reasons; the primary one being that building a hydrogen refuelling station is extremely expensive (estimated cost of more than $1 million per station), 500 times more costly than building charging stations for electric vehicles (estimated cost of $2,000 per station).[7] Furthermore, there are more models available for electric vehicles in comparison to FCEVs.

There are also a lot of uncertainties surrounding hydrogen; it is not available at sufficient quantities for mass commercialisation, leading to extremely high prices.

While Singapore does have ENGIE lab on Semakau Island that is researching on and utilising renewable hydrogen, there is still a lack of suitable infrastructure of renewable hydrogen to ensure mass-production to support the island. Homegrown firm Spectronik has been using hydrogen fuel cells for surveillance drones; it is now looking into expanding its operations to include manufacturing of hydrogen fuel cell vehicles.

While FCEVs have not been entirely ruled out as a possible mode of transport in Singapore, experts are of the opinion that large-scale adoption of FCEVs in everyday use will still not occur anytime in the near future. Even if we adopted FCEVs, given their larger range capacity and higher power density in comparison to other vehicles, we would probably use them for heavy duty transportation instead of personal transportation.

Figure 5: Engie Lab's hydrogen refuelling station[8]

[6] According to Deloitte's Fuelling the Future of Mobility Report
[7] Industry estimates
[8] Image credit to Engie Singapore

1.4.2 THE FUTURE OF FUEL

Although FCEVs and their charging stations may be expensive to produce, various industries are now looking into using hydrogen as a fuel for other purposes. This section will analyse the impact of hydrogen on the automotive industry.

Hydrogen has historically been regarded as the revolutionary alternative to fossil fuels. However, given the past strong foothold the oil and gas industry had on various industries, there was little incentive to create new economies around hydrogen.

Nonetheless, recent years have marked a turning point for hydrogen; since the 2015 Paris climate agreement, governments have been adopting net zero targets and finding ways to reduce carbon emissions in an attempt to stick to their pledge to keep the rise in global average temperature well below 2℃.

Following the global shift towards hydrogen, in the beginning of 2021, more than 30 countries have released hydrogen roadmaps, and governments have committed more than USD 70 billion in public funding to support hydrogen initiatives. The Hydrogen Insights Report 2021[9] predicts that should all hydrogen projects be successfully carried out (there are currently more than 200 worldwide hydrogen projects), total investments will exceed USD 300 billion by 2030. This is equivalent to 1.4% of global energy funding.

Some oil and gas giants are eagerly banking on hydrogen to once again establish a foothold in the energy and fuel industry. For instance, Shell is looking at scaling up in green hydrogen and is installing the world's largest hydrogen electrolyser in Germany. Measures have to be set in place to ensure that production of hydrogen is done in a sustainable manner. This extremely important, especially when we take into account how 95% of hydrogen is still reliant on being sourced from fossil fuels.

Figure 6: Mock-up of Shell's Rhineland hydrogen plant[10]

9 A joint report by the Hydrogen Council and McKinsey & Company.

10 Image credit to fuelcellworks.com and Shell

While hydrogen itself is a clean fuel, manufacturing it is often energy-intensive and produces carbon emissions. Green hydrogen production is the cleanest hydrogen resource as it uses renewable energy to create hydrogen fuel. However, there are some sceptics who question if hydrogen will be adopted large-scale in the transport industry, given existing barriers to entry such as high manufacturing and infrastructure costs.

Although Wood MacKenzie predicts that green or low-carbon hydrogen will be cost-competitive by 2040, widespread adoption and integration of hydrogen might take longer than expected depending on factors such as the country's access to renewable energy.

Singapore is not left behind in the global exploration into hydrogen; we are also considering low-carbon technologies. The Low-Carbon Energy Research Funding Initiative (image below), announced in October 2020, will use around S$49 million to explore the supply, storage and downstream uses of hydrogen, as well as carbon capture and storage for use in building materials or fuels. Further analysis into the future of Singapore's energy production will be included in the sections below.

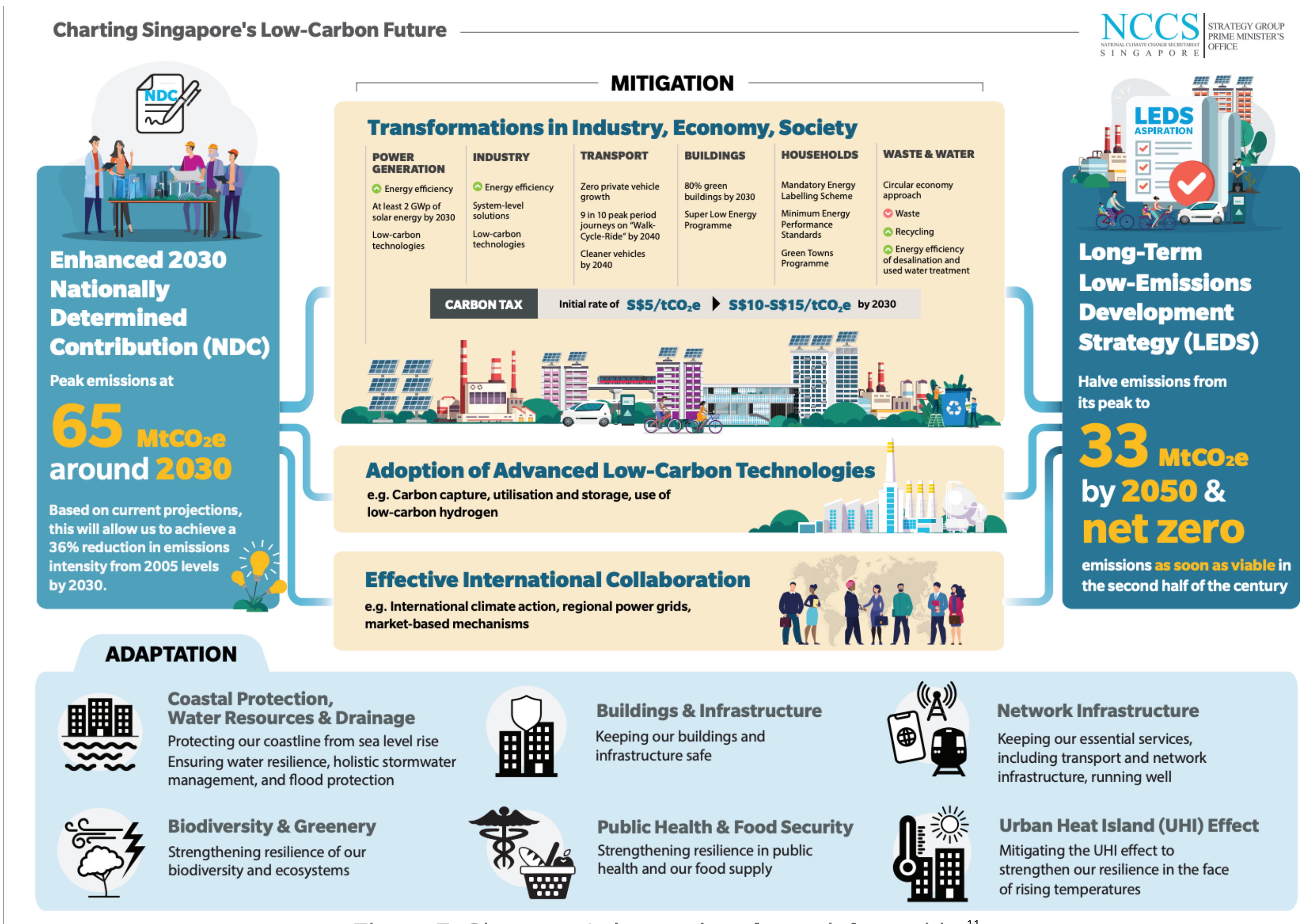


Figure 7: Singapore's low-carbon future infographic [11]

[11] Image credit to National Climate Change Secretariat. Full infographic can be found on their website.

1.5 OVERALL DIFFERENCES BETWEEN THE VEHICLES

Features	BEVs	PHEVs	HEVs	FCEVs	ICE Vehicles
Engine	No ICE engine; runs on electricity	Uses electric motor, then ICE engine	ICE engine and electric motor	Hydrogen fuel cell	Combustion engine
Battery Range	200km – 500km	Electric Motor: 20km – 100km	NA	400km – 800km	NA
Tailpipe Emissions	None	< than ICE	< than ICE	None	Most
Energy Efficiency[12]	70% – 95%	60% – 70%	30% – 50%	60%	20% – 50%
Refuelling Time	Fast Charge: 20mins – 1h Overnight Charge: 8h	Electricity: 20min – a few hours[13] ICE: 5 – 10min	5 – 10mins	10mins	5 – 10mins
Fuel Source	Electricity	Electricity and petrol	Petrol	Hydrogen	Petrol
How Green is the Refuelling	Depends on source of electricity	Depends on source of electricity	Not green	Depends on source of hydrogen	Petrol
Estimated Emission Footprint[14]	110g CO2e/km	130g CO2e/km	140g CO2e/km	40g CO2e/km	200g CO2e/km
Suitability	Shorter trips (urban driving)	Longer trips	Longer trips	Larger vehicles / cargo, longer trips	Longer trips

Figure 8: Summarised differences across vehicle types

[12] Degree of effective use of energy drawn from the battery or fuel tank to move the vehicle

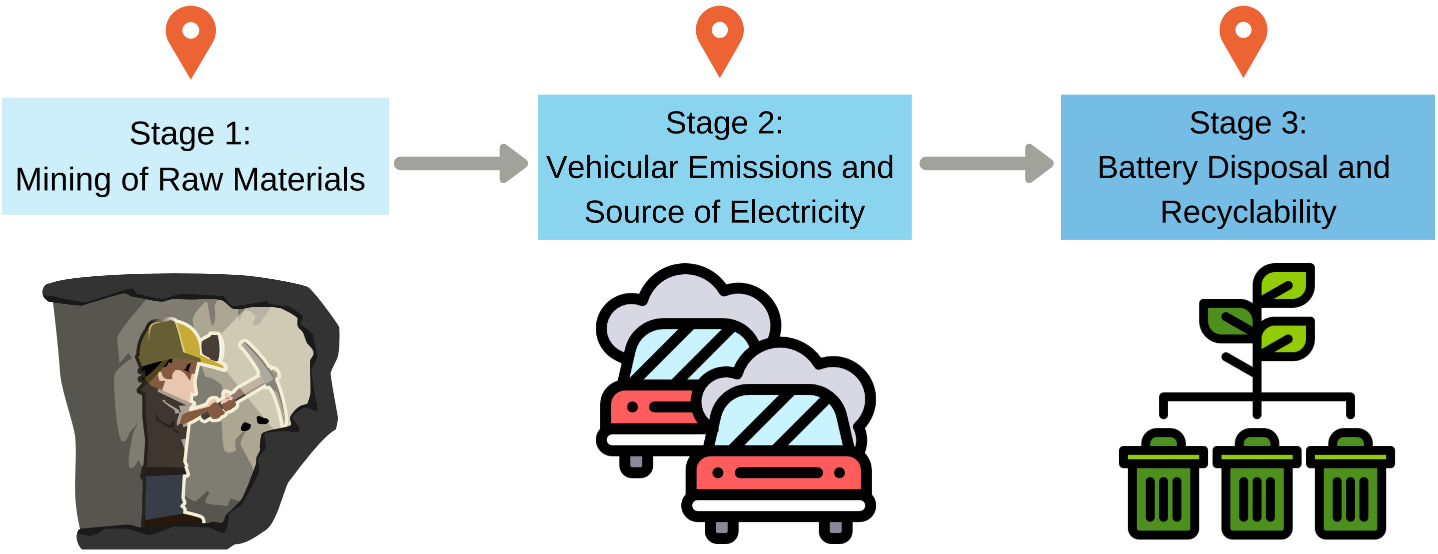
[13] Depending on charger used

[14] Environmental impact of the vehicle throughout its lifespan: includes emissions related to fuel production, processing, distribution, and use. Figures may vary based on distance travelled, source of electricity etc. Based on 2017 South Korea figures.

2. HOW ENVIRONMENTALLY FRIENDLY ARE EVS?

While it is generally known that EVs are more environmentally friendly than ICE vehicles due to its running on electricity with lesser tailpipe emissions, we need to also consider its life cycle environmental impact[15]. A 2020 Deloitte report projects that the manufacturing of BEVs leaves a greater carbon footprint than that of FCEVs and ICE vehicles. The manufacturing of the battery forms the largest greenhouse gas emission in the BEV’s lifecycle due to the energy-intensive process of manufacturing lithium-ion batteries.

The following sections will breakdown life cycle emissions into 3 main stages for analysis.



[15] Assessment of total environmental impact of the vehicle, including source of raw materials, distribution, disposal etc.

2.1 STAGE 1: MINING OF RAW MATERIALS

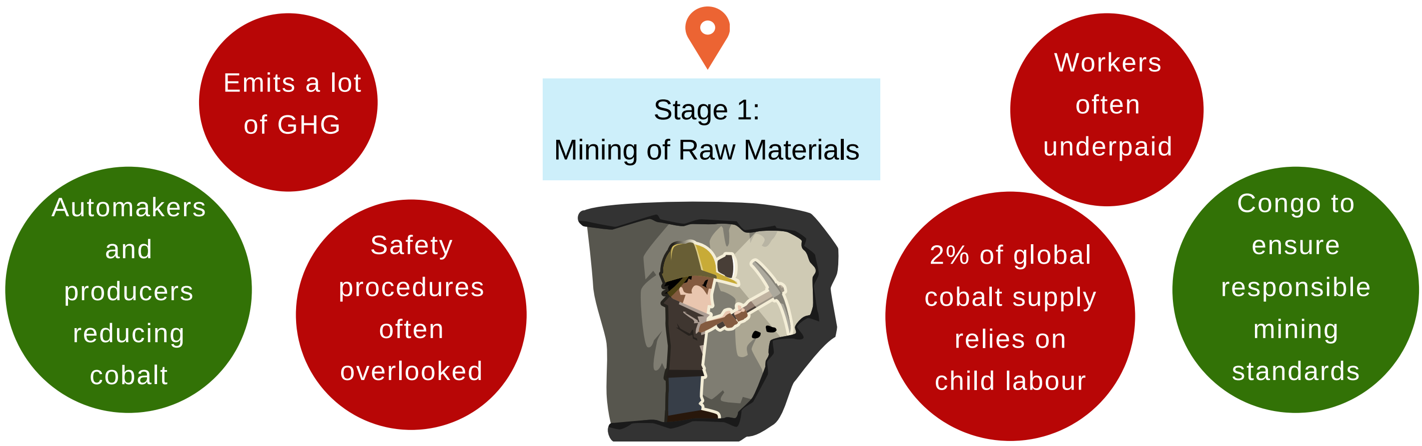
Although EVs have been touted as the "greener vehicle alternative", it can only really live up to its title if it's entire life cycle is zero emissions. Some question if this EV solution actually creates more problems in its production; the sourcing of materials for EV batteries, and disposal of such batteries is typically problematic.

Manufacturing lithium-ion batteries requires extracting and refining rare earth metals such as lithium and cobalt, which requires a lot of energy due to the high heat and sterile conditions involved. Nearly 50% of BEV's life cycle greenhouse gas emissions comes from the assembly and manufacturing of the battery while the other half comes from mining, processing and refining the raw materials. On average, producing EV batteries incurs 125 kg CO2 eq/kWh.[16]

According to IHS Markit, over 90% of lithium produced will be used for batteries.

While it is expected for production of such rare minerals to meet growing demand, as more producers fight for a slice of the EV cake, there is concern over the ethics and sustainability behind the mining process. The mining of cobalt is especially worrying, with approximately 2% of global cobalt supply relying on child labour and 70% of global supply of cobalt being from Congo.[17] With cobalt prices jumping by almost 40% to more than USD20 a pound, cobalt mining is extremely lucrative to Congo.[18] However, safety procedures are often overlooked and workers are unfairly paid in the name of profit.[19] The instability in Congo bears a geopolitical risk to the global supply of cobalt that it lies on.

In the heart of the green technology revolution that we are in, immediate action has to be taken to resolve the exploitative mining of cobalt.



Automakers such as Tesla and Volkswagen have voiced their desire to shift away from using such unethical supply chains, and are currently searching for cobalt alternatives, or attempting to ensure mining is done more sustainably. Congo has also established the new state-backed Enterprise Generale du Cobalt to ensure responsible mining standards and fairer remuneration. Battery makers such as Panasonic are also currently looking to reduce the cobalt content in their batteries.

Ultimately, as the global EV industry grows, and the global supply chain draws more attention, there is hope for such unethical and non-sustainable mining practices to be scrutinised and improved upon.

[16] Based on the International Council on Clean Transportation report
[17] According to Deloitte's Fuelling the Future of Mobility Report
[18] According to The New Yorker article *The Dark Side of Congo's Cobalt Rush*

2.2 STAGE 2: VEHICULAR EMISSIONS AND SOURCE OF ELECTRICITY

EVs do not produce any tailpipe (tank-to-wheel) emissions as it lacks an internal combustion engine. However, an EV's electricity usage is only as green as its source — EVs can only be considered truly environmentally friendly if they draw energy from renewable sources. Hence, we will be looking at well-to-wheel[19] (subsuming tank-to-wheel and well-to-tank) BEV emissions.

Currently, EVs in Singapore draw electricity from the grid, which is still fossil fuel-based. Motor vehicles in Singapore emit about 6.4 million tonnes[20] of carbon dioxide equivalent[21] annually. A BEV's well-to-wheel emissions are close to 0.6 kg CO2-eq/kWh, which is lower in comparison to its petrol or diesel equivalent (both approximately 0.3 kg CO2-eq/kWh).

If all light vehicles (cars and taxis included) ran on electricity, this would reduce up to 2 million tonnes per year, cutting total national emissions by 4%. Even in the situation where all electricity is generated by fossil fuels, there will be carbon savings of up to 50%.[22]

Hence, although there are some concerns over sourcing electricity from power plants, since 95% of Singapore's power generation comes from natural gas, the cleanest form of fossil fuels, there is still a sizeable reduction of 50% in carbon emissions. Although the source of energy is ultimately still from fossil fuels, and the greenest source would be from renewable sources of energy, the geographical location of Singapore just above the equator means we have little access to wind or tidal action to harness renewable energy from. Given our land-scarce nation, the likelihood of being able to rely on large solar farms to harness solar energy is also relatively low.

However, there are still some attempts to incorporate renewable energy into our transportation. For instance, Bus operator Go-Ahead Singapore is currently monitoring 2 public buses fitted with ultra-thin solar panels in a six-month proof-of-concept trial.

Figure 9: Go-Ahead bus fitted with solar panels[23]

[19] Also known as life cycle analysis: includes emissions of fuel while driving, and production of the energy source (petrol, diesel, electricity etc).
[20] According to then-Minister of Transport Ong Ye Kung's (now Minister for Health) speech on Singapore Green Plan 2030 at the Committee of Supply Debate 2021.
[21] Carbon dioxide equivalent is used as a metric to compare the emissions from various greenhouse gases based on their global warming potential.
[22] See footnote 21.
[23] Image credit: Minister Ong Ye Kung's Facebook

The solar panels can generate a total of 1,000 watts of energy, which is used to charge the battery on the buses. The panels are projected to help Go-Ahead Singapore save 3-4% of the fuel that is typically consumed by the buses. Though the solar panels are not able to generate enough power to sustain the bus the entire day, there is still an expected reduction of 3.7 tonnes of carbon. The possibility of completely switching our bus fleet to run on solar energy is likely a faraway one.

Nonetheless, there is still some hope for switching to cleaner, renewable energy in Singapore's future.

Five institutions (the National Climate Change Secretariat, the Economic Development Board, the Energy Market Authority, the Maritime and Port Authority and the Civil Aviation Authority of Singapore) have been commissioned to analyse the feasibility of using low-carbon technological solutions and using hydrogen as fuel.[24] Recent findings from this study have shown that, given Singapore’s limited renewable energy resources, it is unlikely for us to be able to produce green hydrogen using domestic green electricity. Research is now being done to identify possible affordable means of importing low-carbon hydrogen. In addition to this, Singapore seeks to diversify her energy supply with four different “switches”[25] (methods), as seen in the figure below. Hence, the likelihood of using greener fuel is somewhere on the horizon.

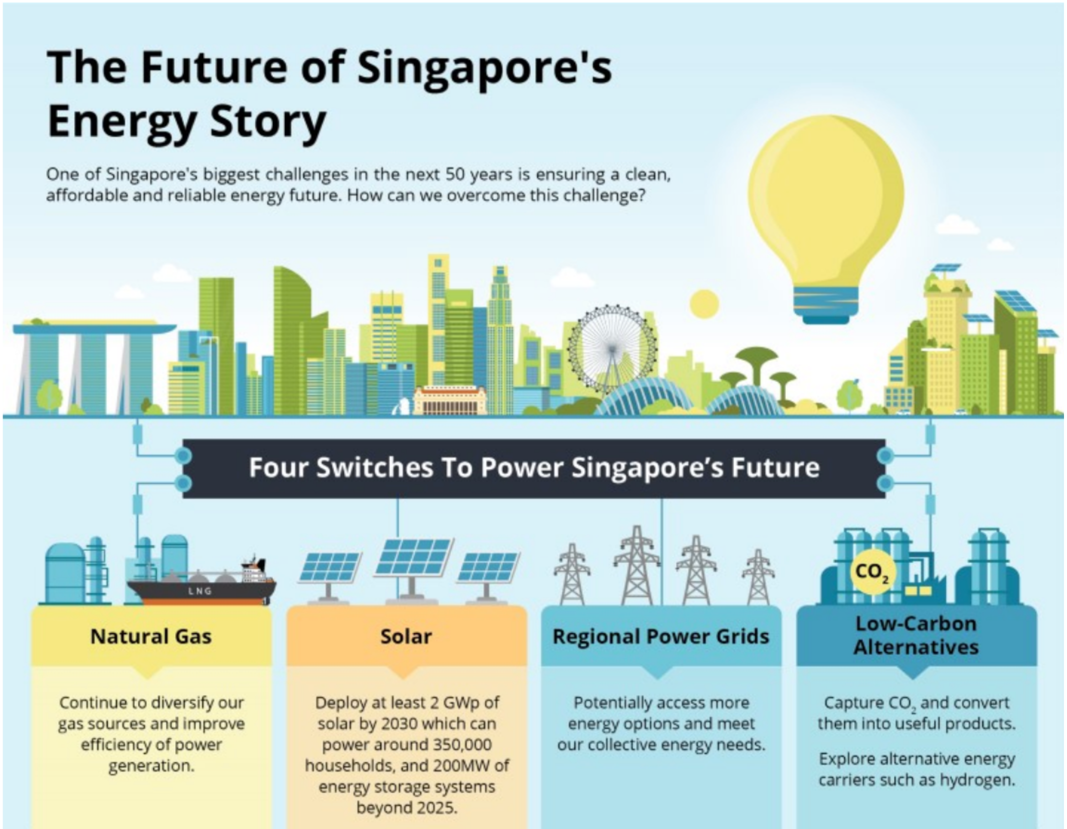
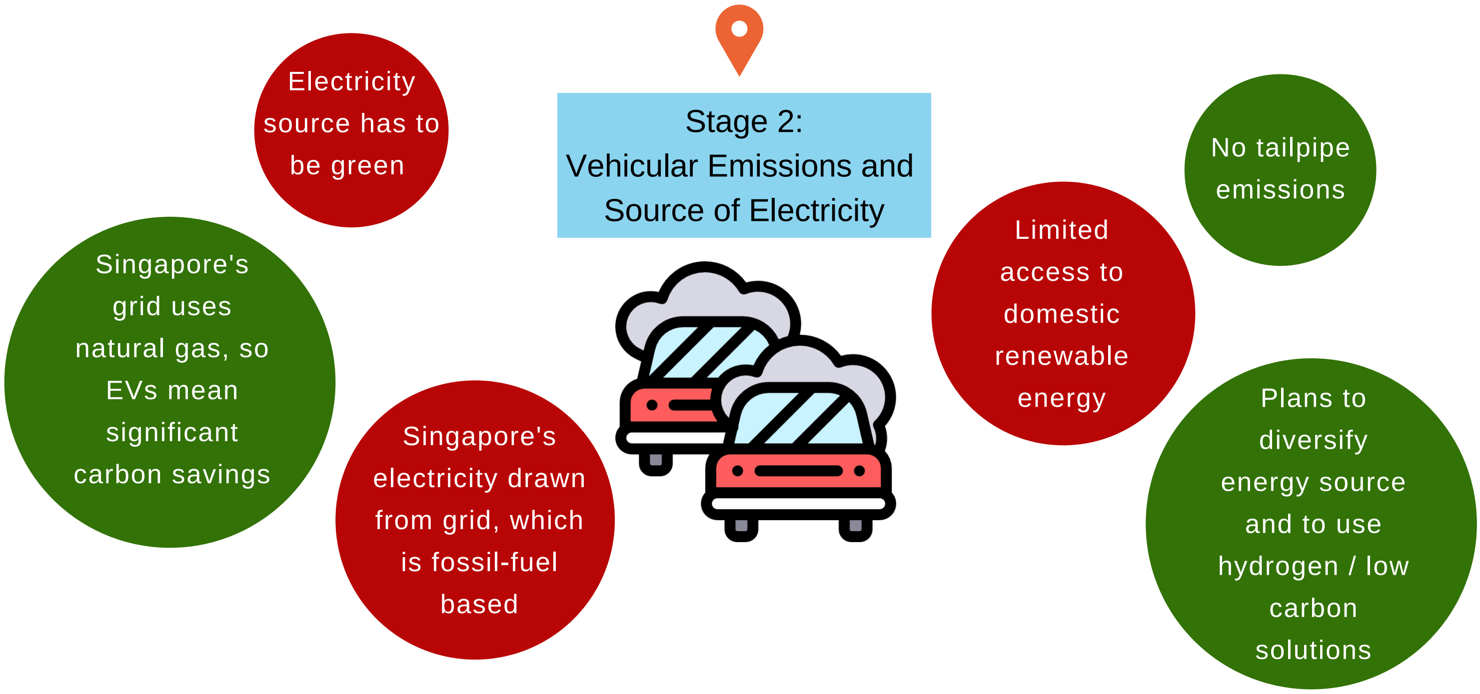


Figure 10: Singapore diversifying her energy sources[26]

[24] According to their 2021 joint press release
[25] According to Energy Market Authority Singapore
[26] Image credit to Energy Market Authority Singapore



2.3 STAGE 3: BATTERY DISPOSAL AND RECYCLABILITY

Despite the gloomy projection that the manufacturing process of BEVs incurs a larger carbon footprint than that of FCEVs and even ICE vehicles, not all hope is lost — BEVs can offset their negative environmental impact if its materials are recycled and disposed of properly.

The lifespan of the modern battery is estimated to be around 10 years. Giving these batteries a new lease of life after these 10 years would ideally offset the environmental costs incurred to mine and manufacture them in the first place.

If recycling or disposal of batteries is not done properly, i.e. batteries are left in landfills, the toxic metals from the batteries such as cobalt could leak into the environment and lead to water and soil contamination.

60,000 tonnes of electronic waste is generated by Singapore annually, and this number is only expected to grow in the near future,[27] so it is of great importance that we find ways to minimise the negative environmental impacts of not disposing of and recycling our e-waste properly. Currently, in Singapore, the onus of responsibly disposing e-waste is on consumers, with designated e-waste recycling bins situated in various public amenities. However, legislation will soon shift this responsibility to producers.[28]

Figure 11: Singapore's Semakau landfill [29]

[27] According to towardszerowaste.gov.sg
[28] Companies which manufacture or import electrical or electronic products into Singapore
[29] Image credit to National Environment Agency

The National Environment Agency has implemented the Extended Producer Responsibility Programme through the Resource Sustainability Act which will start from July 2021. The programme is meant to regulate our e-waste system to ensure proper collection and handling of e-waste and the extraction of valuable resources from e-waste. Producers now bear the responsibility for collecting and handling their products when they reach the end of their shelf life. The NEA has awarded the license to operate a Producer Responsibility Scheme to ALBA Group plc & Co. KG (ALBA), who will collect consumer e-waste for proper recycling on behalf of producers from 1 July 2021 to 30 June 2026.

The government is also encouraging other players to establish e-waste recycling plants in SG. For instance, local company e-waste recycler TES-Amm has opened a factory in Singapore that looks into reclaiming more than 90% of precious matters in used lithium-ion batteries. Minerals such as lithium, cobalt and graphite are extracted from the disposed batteries, which is then reused for new battery production.

Figure 12: TES-Amm worker sorting out materials[30]

With the advent of technology and social media, smart devices have become integral to our daily lives, leading to high penetrations of phones, laptops and tablets, which all require the mining of rare minerals such as lithium and cobalt. Extraction and recycling of minerals would ideally give them a second lease of life, reducing the need to mine minerals from the environment.

EV batteries often have to meet the highest standards in terms of quality. However, when they reach the end of their shelf life and we can reuse them for second-life applications,[31] we can use them for other applications that do not demand the same level of quality i.e. stationary power applications. This would help to support the electric grid, which is important as EV charging infrastructure increases in the coming years.

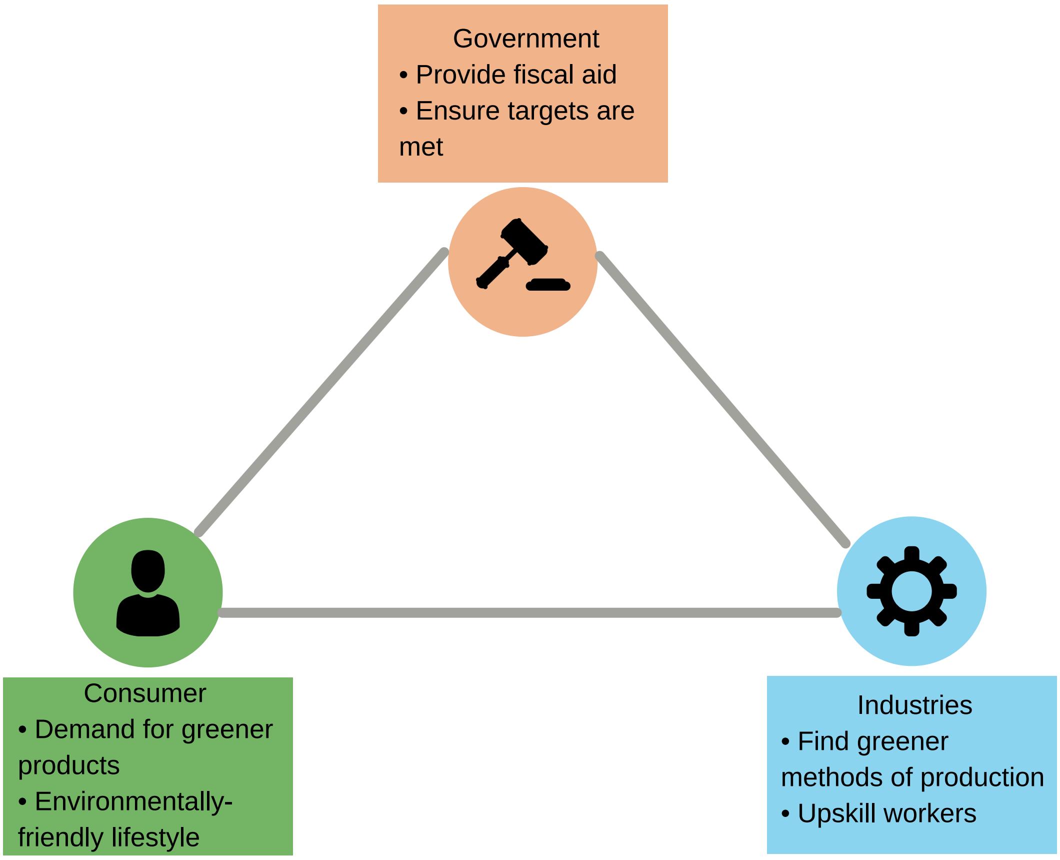
Though there might be some concern over how much energy is used to even recycle these parts in the first place, TES relies largely on renewable energy via rooftop solar panels to power the recycling plant, as well as repurposed electric bus batteries to store the solar energy to allow ease of use.

Figure 13: TES-Amm's rooftop solar panels[32]

[30] Image credit: TES-Amm Singapore
[31] EV batteries can still retain 70-80% of their initial capacity at the end of their shelf life
[32] See footnote 30

There is a global imperative to work on moving towards a circular EV economy; automakers such as Toyota plan to install retired batteries outside 7-Eleven stores in Japan to store power generated from solar panels to use it inside the stores. Tesla has also worked with recycling companies to recycle their battery packs in the US and Europe. Various Original Equipment Manufacturers (OEMs) are also re-examining their supply chains to make their processes carbon-free; some have shifted their battery plants close to OEMs to lower carbon transport costs, or even power their plants with carbon-free, water-generated electricity.

With the cost of EV batteries now being USD100 per kilowatt-hour, a more than tenfold decrease from USD1,200 in 2010, and investment in EV-related technologies and assets almost doubling in 2020,[33] there is hope that there will be incentive to make battery production and disposable more sustainable. Furthermore, as automakers increase the size of their batteries to enable greater range, battery lifetimes are also expected to increase, similarly leading to longer vehicle lifetimes and improving potential for second-life applications.



Ultimately, the movement towards greener processes requires a cohesive effort among industries, governments and consumers. While the energy, transport and automotive industries work together to find more sustainable methods of production and recycling, coalitions can be formed to hold them accountable. Governments might also have to intervene to ensure targets are met, or that fiscal aid is provided to such industries if need be. Consumers who demand for more sustainable products will also influence and incentivise companies to make that sustainable transformation. It is only with this level of cooperation then will there be hope for impactful, systemic changes that ensures battery production and recycling will no longer be more carbon-intensive than that of ICE vehicles, finally legitimising the "greener vehicle" title EVs have held onto all this time.

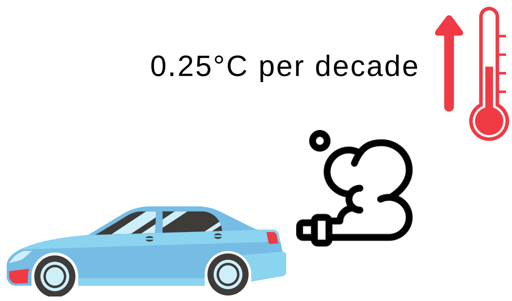
[33] According to McKinsey article *Four key trends in electric cars and mobility*

3. OTHER IMPACTS OF EVS

There are other ways in which EVs affect the environment beyond the typically-discussed lifecycle environmental impacts of EVs; for instance, their effect on the economy and temperature.

3.1 ENVIRONMENTAL IMPACTS (URBAN HEAT ISLAND EFFECT)

According to the Meteorological Service Singapore, Singapore is heating up twice as fast in comparison to the rest of the world, at 0.25°C per decade. This is largely due to the Urban Heat Island (UHI) effect, the degree to which our urban environment is hotter than neighbouring rural areas. There are 2 main causes for UHI, one of which is the heat that is emitted by motor vehicles, power generation plants, air conditioners etc.

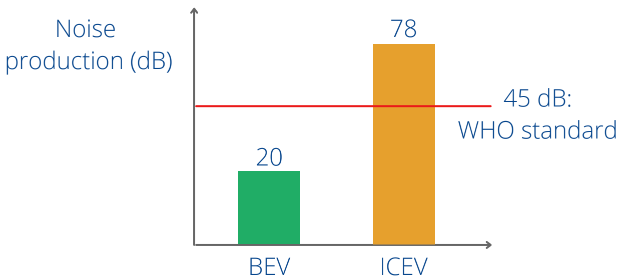


An ICE engine loses up to 60%[34] of its power to heat loss via the radiator and the tailpipe, which means motor vehicles in Singapore contribute a rather significant amount of heat to the environment, given that ICE vehicles currently make up almost 90%[35] of the local car population.

If the UHI effect is not minimised or reduced, as temperature and humidity increases, we could suffer from heat exhaustion or heat stroke. Hence, converting to EVs would reduce the overall heat signature of vehicles on the environment significantly.

3.2 NOISE POLLUTION AND ROAD SAFETY

Without an internal combustion engine, EVs are a lot quieter than ICE vehicles — BEVs are estimated to produce 20dB of noise while ICE vehicles produce approximately 78dB[36] of noise. The World Health Organisation states that long-term exposure to road traffic above 40-50dB could adversely affect one's health e.g. elevating blood pressure. It is expected that using EVs would reduce noise pollution greatly, in turn reducing the likelihood of negative health impacts, or even road rage, of drivers and citizens alike.



However, the relative silence of EVs in comparison to ICE vehicles is not without its drawbacks; there is increasing worldwide legislation and technology introduced to ensure that EVs do produce some form of noise to ensure road safety. If EVs are too quiet, pedestrians may be unable to identify cars in their proximity. Given how pedestrians are likely used to ICE vehicles emitting noise, it is very likely that EVs pose a safety risk if pedestrians cannot hear them, especially when we consider how pedestrians increasingly use their phones or earphones while on the road. In the European Union and the U.K., all new EVs and hybrids have to use an acoustic vehicle alerting system (AVAS) that emits a sound that helps pedestrians identify when a vehicle is near them.

34 According to Green Car Reports
35 Based on LTA Annual Vehicle Statistics 2020
36 According to Nissan Motor Corporation's press release

3.3 ECONOMICAL IMPACT

There are 2 pivotal shifts that we can expect with the trend towards using green technology; firstly, moving towards a circular economy and secondly, a change in the type of skill set that the automotive industry requires.

A circular economy aims to do away with the “take-make-waste” linear model by being regenerative and reducing dependence on finite resources.

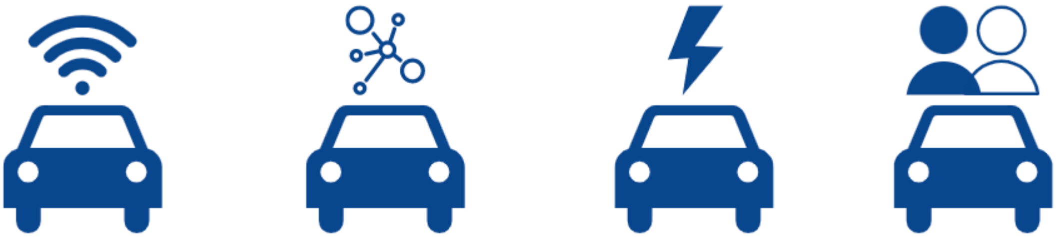
With global EV population across all transport modes (i.e. electric buses, cars, vans etc) projected to hit 145 million in 2030,[37] we can expect the automotive industry to transform and for there to be pivotal shifts in the workforce and demand for skills. These pivotal economic shifts will be discussed in the following sections.

[37] According to IEA EV Global Outlook 2021

4. TECHNOLOGICAL LANDSCAPE: SOFTWARE OF ELECTRIC VEHICLES

There are several watershed moments that will transform the automotive industry — COVID-19 aside, the advent of the Fourth Industrial Revolution (Industry 4.0) and 5G are also expected to cause pivotal changes.

In relation to this, industry experts have identified the 4 major technological trends (ACES) that will shape future mobility:



Autonomous Vehicles

- No human driver required
- Vehicle-to-vehicle communication

Connectivity

- Cars have other functions
- E.g. In-vehicle media streaming, positioning based-services

Electrification

- Reduced emissions
- Cars can connect digitally and perform remote operations

Shared Mobility

- Cars have various users
- E.g. Taxi companies can operate autonomous vehicles with optimised route solutions

Following these technological trends, we can expect major changes in the automotive software industry. We will be focusing on some of these technological trends in our analysis.

With the general trend towards greener vehicles leading to EVs having longer lifespans, automakers now have to differentiate themselves via vehicle software. McKinsey estimates that the automotive software market will grow by approximately 250% by the end of the 2030.

As product lifespan increases, the vehicle remains the same but its software can be updated — this matches technological expectations that cars will be able to perform remote updates in the future. Differential Asia projects that vehicle software updates would look very different in the future, with automakers looking at improving vehicle communication. For instance, vehicles would be able to communicate with each other, and even cloud-based technology to gain information on traffic updates and road conditions. Cars will become increasingly integral to our lives as software improves and becomes more user-centric, going beyond the status quo of just being able to access applications such as Netflix in your car.

As we move towards improving vehicle software, OEMs are now in a neck-to-neck race in innovation. A McKinsey report projects that demand for workers with today's standard skill sets will drop by 30% by 2030 as the industry evolves. Beyond vehicle software, the automotive industry is expected to change in other ways. For instance, as we adopt a circular economy and do away with the industry's current "take-make-waste" model, there will be increasing interest in using technology to transform the supply chain to make it more environmentally friendly. Also, as EV adoption increases globally, the vehicle service sector will be impacted as EVs typically require less servicing due to lack of internal combustion engine. This sector could potentially be replaced or superseded by preference for workers skilled in battery chemicals and recycling.

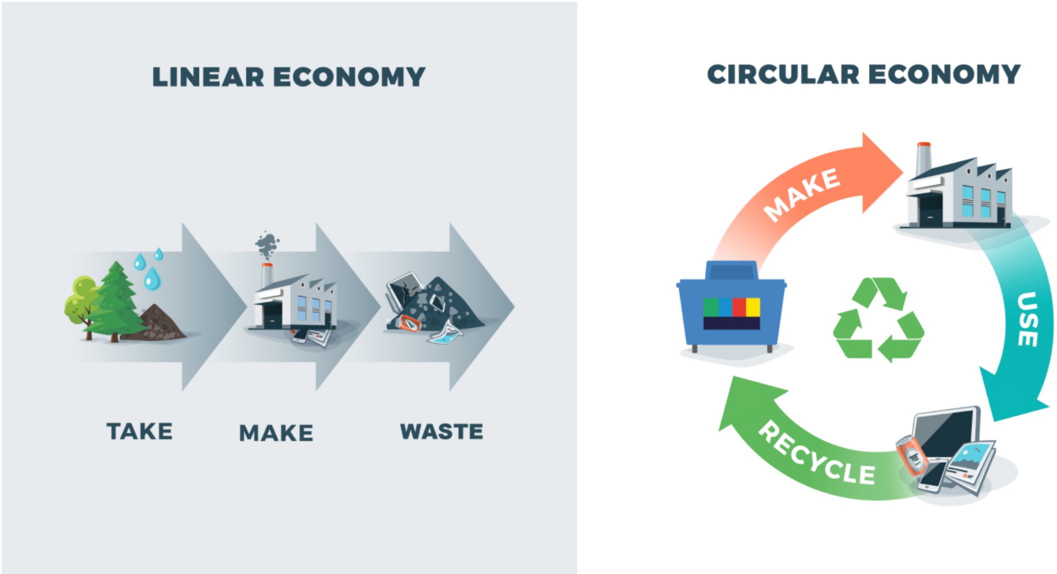


Figure 14: Linear vs Circular economy[38]

To survive, automakers need to reassess their supply chain and current skill sets, and work on upskilling their employees to adapt to such technological changes.

[38] Image credits to Towardszerowaste.gov.sg

5. ELECTRIC VEHICLES' ARMS RACE

With several countries phasing out ICE vehicles and encouraging adoption of BEVs, OEMs are locked in an EV arms race as they seek to electrify their production. More OEMs are increasingly announcing their shift to producing and selling mostly, or only zero-emission vehicles in the near future.

A timeline of the top 10 OEMs with the highest car population in Singapore[38] and their announcements[39] of phasing out ICE vehicles to manufacture electric vehicles are displayed in the image[40] below.

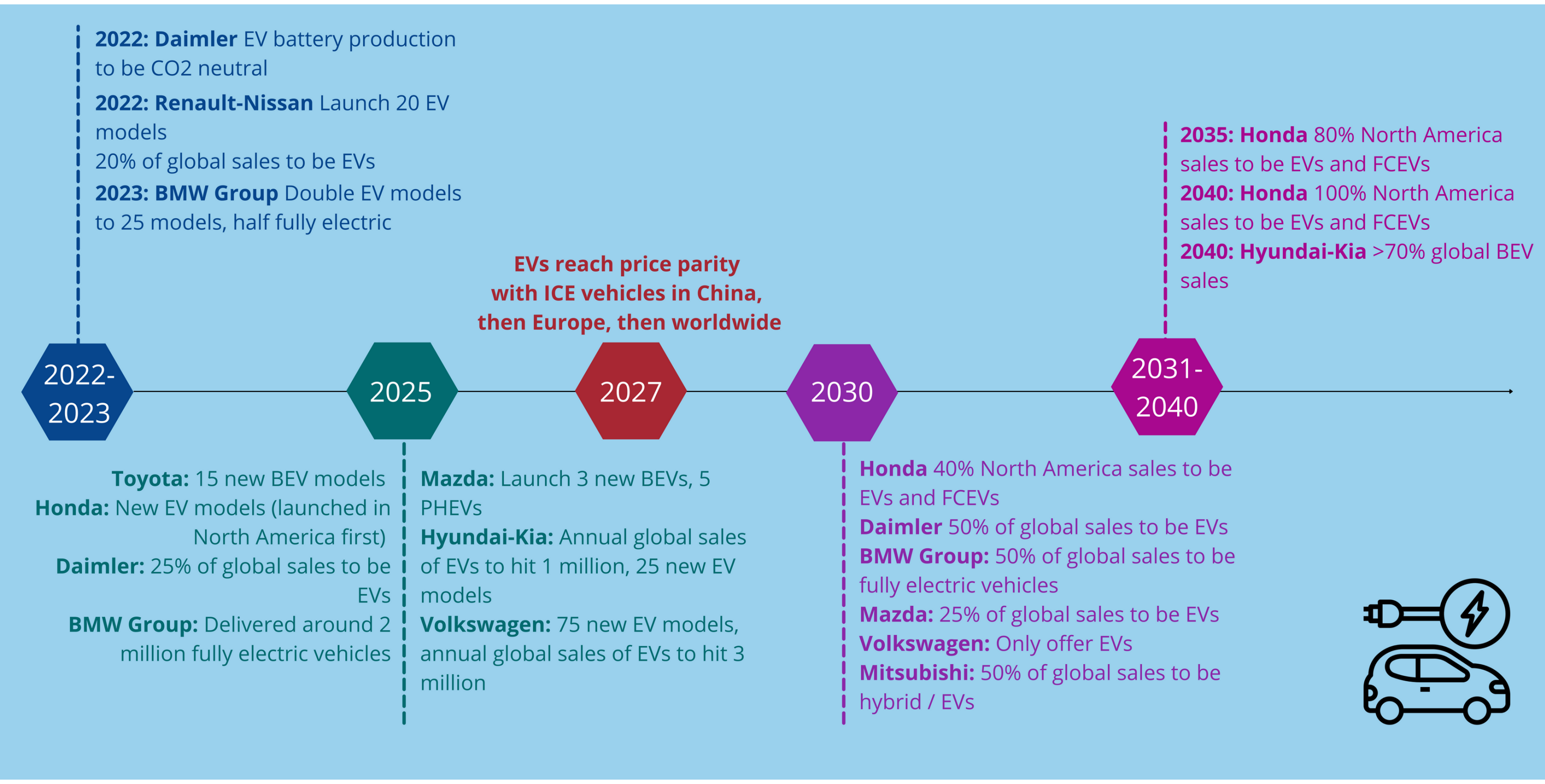


Figure 15: Timeline of EV targets for OEMs

IHS Markit projected that 2027 is the year when EVs and ICE vehicles first reach price parity. Notably, past 2027, OEMs' sales of EVs are expected to rise significantly. Even before 2027, several OEMs are already planning to launch more EV models and increasing sales in expectation of increased consumer demand for EVs that comes with its affordability. IHS Markit predicted that BEV passenger car sales will hit 23.5 million in 2030, approximately 26.4% of total global sales of 89 million cars in 2030.

[38] Based on LTA data on car population on the road, as of 2020
[39] Information is up to date as of date of publication
[40] Targets have been taken from sources such as automakers' press releases

A timeline of OEMs' FCEV and hydrogen goals are displayed in the image below. It is noticeably not as optimistic as that of EVs, given various factors such as high costs and lack of charging infrastructure. However, some OEMs are developing FCEVs in preparation for increased usage of hydrogen.

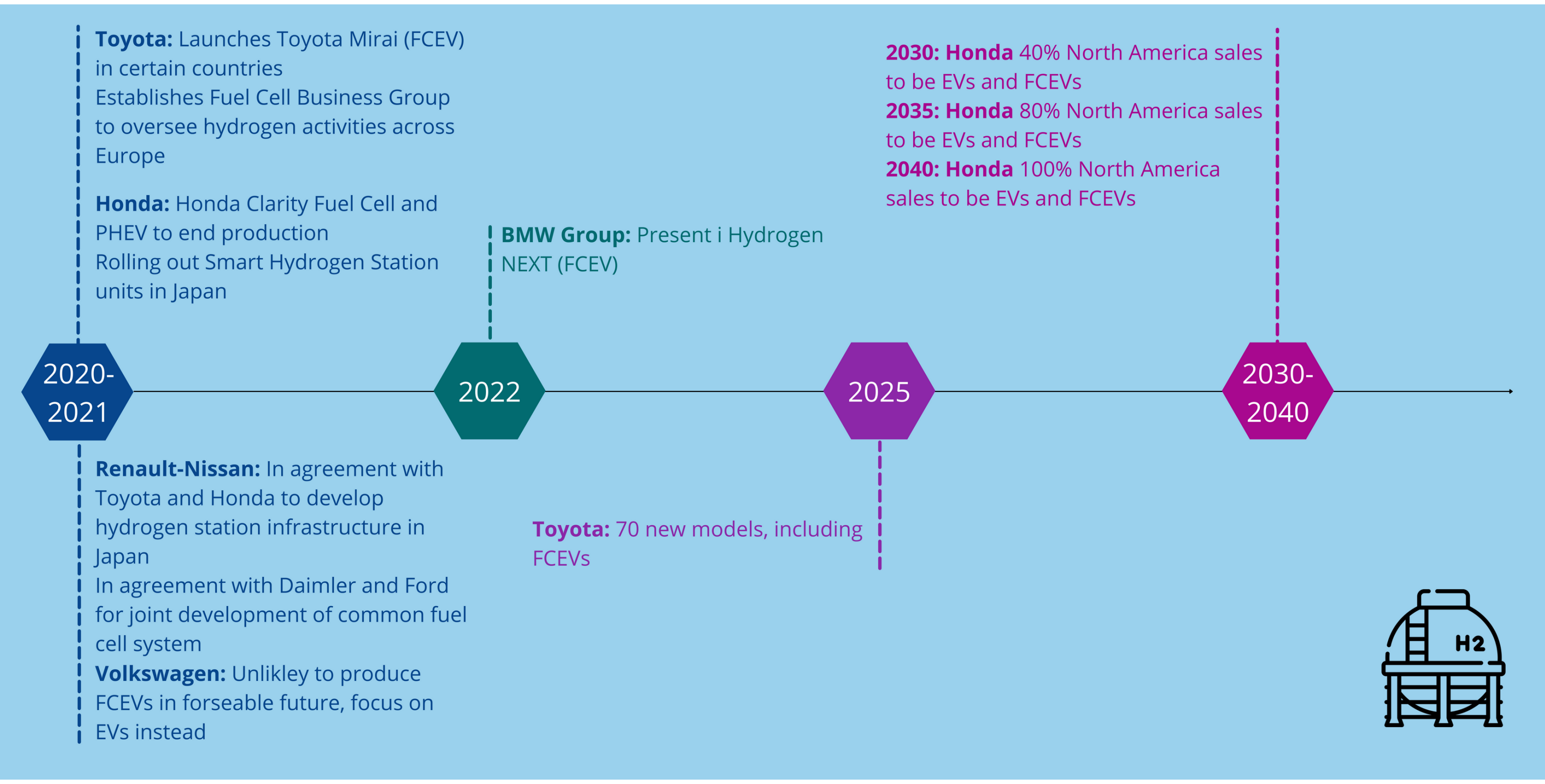


Figure 16: Timeline of FCEV targets for OEMs

OEMs are locked in a fierce arms' race to gain a foothold in the EV industry; we can expect to benefit from more EV models that promise to suit different consumer profiles and preferences.

6. CONCLUSION

Purchasing a vehicle, set against the backdrop of a world that is rapidly evolving and becoming more environmentally conscious, means that our decision to purchase no longer solely depends on how "affordable" said vehicle is. With a multitude of factors shaping our consumer choice — the 4 technological trends impacting vehicle software, OEMs seeking to reduce carbon emissions, governments imposing limitations on the kind of vehicles we can buy — it is hard to ignore how the automotive industry will go through pivotal changes, signalling similar changes in the type of vehicles we can buy. Having some knowledge of these expected changes, or the types of vehicles, would aid us greatly in our decision making.

The global shift to electrification is underway; focus is now increasingly placed on the environmental impacts of the manufacturing process. The other impacts of EVs also need to be considered; its impact on noise pollution, air pollution and our health. It takes the collective effort of consumers, manufacturers and governments to ensure that EVs are green in totality, and that the manufacturing process will not harm the environment even more than ICE vehicles, or the move to EVs will not be sustainable in the future either.

As OEMs prepare to increase EV sales, and reduce ICE vehicle sales, they need to also take into account not only technological changes, but also economic changes — the industry's demand for skills will change, and OEMs need to ensure their workforce follow suit or risk getting left behind in the EV arms race. Furthermore, they need to prepare for fundamental shifts in their manufacturing process as they move towards circular production.

Nonetheless, it is also important to keep other alternative fuels in mind; while hydrogen FCEVs are less established than EVs, exploring hydrogen should still be a priority. In the foreseeable future, mass adoption of hydrogen FCEVs might be relatively slow for personal vehicles, and might be more suitable for long-distance, heavy-cargo transportation. Ultimately, EVs are still more suitable for commercial use in Singapore, although the greenest method of transportation would be public transport. In the coming years, consumer preference for public transport would depend on its user-friendliness, convenience and suitability to one's lifestyle.

REFERENCES

Adler, K. (2021, May 3). *Global electric vehicle sales grew 41% in 2020, more growth coming through decade: IEA.* IHS Markit. https://ihsmarkit.com/research-analysis/global-electric-vehicle-sales-grew-41-in-2020-more-growth-comi.html#:~:text=Starting%20in%202027%2C%20IHS%20Markit,be%20electric%20(nearly%2027%25).

Alternative Fuels Data Center. (n.d.). *How Do Fuel Cell Electric Cars Work?* https://afdc.energy.gov/vehicles/how-do-fuel-cell-electric-cars-work

Ang, H. M. (2021, January 5). *Electricity demand expected to rebound as economy recovers from COVID-19 fallout: MTI.* Channel News Asia. https://www.channelnewsasia.com/news/singapore/electricity-demand-dropped-covid-19-expected-to-rebound-mti-13895548

Barreto, V. (2015, June 3). *Why are electric and hybrid electric vehicles more efficient than conventional ones?* GeoTab. https://www.geotab.com/blog/why-hybrid-vehicles-are-more-efficient/

BMW Group. (2021, June 16). *Everyday testing of BMW i Hydrogen NEXT with hydrogen fuel cell drive train begins.* [Press Release]. https://www.press.bmwgroup.com/global/article/detail/T0334225EN/everyday-testing-of-bmw-i-hydrogen-next-with-hydrogen-fuel-cell-drive-train-begins?language=en#:~:text=The%20BMW%20i%20Hydrogen%20NEXT%20is%20a%20pure%20electric%20vehicle,electricity%20in%20a%20fuel%20cell.

BMW Group. (2021, May 12). *Over 200 million tonnes: BMW Group sets ambitious goal to reduce CO2 by 2030.* [Press Release]. https://www.press.bmwgroup.com/global/article/detail/T0332273EN/over-200-million-tonnes-bmw-group-sets-ambitious-goal-to-reduce-co2-emissions-by-2030

Buechel, C., Bednarski, L. & Wietlisbach, S. (2021, February 8). *As lithium-ion battery materials evolve, suppliers face new challenges.* IHS Markit. https://ihsmarkit.com/research-analysis/lithiumion-battery-materials-evolve-suppliers-face-new-challenges.html

Carnell, R. & Sakpal, P. (2021, February 23). *Singapore Green Plan 2030 — Important steps towards a sustainable future.* THINK Economical and Financial Analysis. https://think.ing.com/articles/singapore-green-plan-2030-important-steps-towards-a-sustainable-future

Changaroth, S. (2021, April 23). *Torque Shop: Fuel cell EVs.* The Straits Times. https://www.straitstimes.com/life/motoring/torque-shop-fuel-cell-evs

Choi, W., Yoo, E., Seol, E., Kim, M., & Song, H. H. (2020, March 17). *Greenhouse gas emissions of conventional and alternative vehicles: Predictions based on energy policy analysis in South Korea. Applied Energy, 265,* 114754.

CNA Insider. (2020, October 10). *Are Electric Cars Really Good for the Environment?* YouTube. https://www.youtube.com/watch?v=qdoEmebP-b0&t=427s

REFERENCES

CNA Insider. (2021, June 21). *Electric Cars: Can Vehicles Really Be Zero Emission?* YouTube. https://www.youtube.com/watch?v=s-_NwAZ5PFU&ab_channel=CNAInsider

Daimler. (n.d.). *Ambition 2030: Our path to CO2-neutrality.* https://www.daimler.com/sustainability/climate/ambition-2039-our-path-to-co2-neutrality.html

Deloitte. (2020). *Fueling the Future of Mobility: Hydrogen and fuel cell solutions for transportation.* https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/finance/deloitte-cn-fueling-the-future-of-mobility-en-200101.pdf

Electric Vehicle Association of Singapore. (2021, March). *Singapore Electric Vehicle Guide 2021.* https://www.evas.org.sg/#ev-guide-2021

Energy Market Authority of Singapore. (n.d.). *Singapore's Energy Story.* https://www.ema.gov.sg/ourenergystory

Energy Research Institute (ERI@N) of Nanyang Technological University. (n.d.) *E-Mobility Technology Roadmap.* https://www.nccs.gov.sg/docs/default-source/default-document-library/e-mobility-technology-roadmap.pdf

Eveland, J. (n.d.) *Ways to beat the heat: The latest Cooling Singapore study is finding new ways to keep Singapore cooler and everyone can play their part.* Urban Redevelopment Authority. https://www.ura.gov.sg/Corporate/Resources/Publications/Skyline/Skyline-Issue10/Beat-the-heat

EVGo. (n.d.). *Types of Electric Vehicles.* https://www.evgo.com/ev-drivers/types-of-evs/#60

Feblowitz, J. (2020, October 27). *The Colours of Hydrogen – Brown, Grey, Blue and Green – Think About It.* Utility Analytics Institute. https://utilityanalytics.com/2020/10/the-colors-of-hydrogen-brown-grey-blue-and-green-think-about-it/#:~:text=Hydrogen%2C%20in%20itself%2C%20is%20a,intensive%20and%20has%20carbon%20byproducts.&text=The%20process%20for%20producing%20grey,the%20creation%20of%20grey%20hydrogen.

Frangoul, A. (2021, June 4). *As electric vehicle sales surge, discussions are now turning to noise and safety.* CNBC. https://www.cnbc.com/2021/06/04/as-electric-vehicle-sales-surge-discussions-turn-to-noise-and-safety-.html

FuelEconomy.Gov. (n.d.). *How Hybrids Work.* https://www.fueleconomy.gov/feg/hybridtech.shtml

Hall, D. & Lutsey, N. (2018, February) *Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions.* The International Council on Clean Transport.

Heineke, K., Ménard A., Södergren, F. & Wrulich, M. (2019, June 27). *Development in the mobility technology ecosystem – how can 5G help?* McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/development-in-the-mobility-technology-ecosystem-how-can-5g-help

Home, A. (2021, May 13). *Column: Cobalt, Congo and a mass artisanal mining experiment.* Reuters. https://www.reuters.com/business/energy/cobalt-congo-mass-artisanal-mining-experiment-andy-home-2021-05-13/

REFERENCES

Honda. (2021, June 28). *New Honda Prologue SUV Begins Next Chapter in Brand's EV Direction in North America.* Honda News Room. https://global.honda/newsroom/news/2021/4210628eng.html

Honda. (2021, April 23). *Honda Targets 100% EV Sales in North America by 2040, Makes New Commitments to Advances in Environmental and Safety Technology.* [Press Release]. https://hondanews.com/en-US/honda-corporate/releases/release-32797eaea7316f1bed4bfcd27919f703-honda-targets-100-ev-sales-in-north-america-by-2040-makes-new-commitments-to-advances-in-environmental-and-safety-technology

Hydrogen Council & McKinsey & Company. (2021). *Hydrogen Insights 2021.* https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021.pdf

Hyundai. (2018, December 11). *Hyundai Motor Group reveals "FCEV Vision 2030".* [Press Release]. https://www.hyundai.news/eu/articles/press-releases/hyundai-motor-group-reveals-fcev-vision-2030.html

IHS Markit. (2021, April). *Pivoting to an Electrified Future - The Auto Industry Amps Up.*

International Energy Agency. (2021). *Global EV Outlook 2021,* IEA, Paris. https://www.iea.org/reports/global-ev-outlook-2021

International Energy Agency. (2019). *The Future of Hydrogen,* IEA, Paris. https://www.iea.org/reports/the-future-of-hydrogen

International Renewable Energy Agency. (n.d.). *Hydrogen from Renewable Power.* https://irena.org/energytransition/Power-Sector-Transformation/Hydrogen-from-Renewable-Power

J. D. Power. (2020, November 23). *How a Fuel Cell Vehicle Works.* https://www.jdpower.com/cars/shopping-guides/how-a-fuel-cell-vehicle-works

Kok, Y. (2021, March 30). *Go-Ahead Singapore rolls out 6-month trial of public buses with solar panels.* The Straits Times. https://www.straitstimes.com/singapore/transport/first-public-buses-with-solar-panels-hit-the-road-in-six-month-trial-by-go-ahead

Land Transport Authority. (n.d.). Vehicles by Fuel Type.

Land Transport Authority. (2021). Monthly Vehicle Statistics.

Lovati, S. (2020, May 6). *BEVs vs FCEVs: Competing or Complementary Technologies?* EEWeb. https://www.eeweb.com/bevs-vs-fcevs-competing-or-complementary-technologies/#:~:text=BEVs%20and%20FCEVs%20are%20as,site%2C%20in%20the%20refueling%20stations.

McKinsey & Company. (2021, April 6). *The irresistible momentum behind clean, electric, connected mobility: Four key trends.* https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-irresistible-momentum-behind-clean-electric-connected-mobility-four-key-trends

REFERENCES

National Climate Change Secretariat. (2021, June 23). *Joint Press Release By NCCS, EDB, EMA, MPA, And CAAS - Singapore Looks To Develop And Deploy Low-Carbon Technological Solutions.* [Press Release]. https://www.nccs.gov.sg/media/press-release/singapore-looks-to-develop-and-deploy-lc-technological-solution

National Environment Agency. (n.d.). *Extended Producer Responsibility (EPR) System for E-waste Management System.* https://www.nea.gov.sg/our-services/waste-management/3r-programmes-and-resources/e-waste-management/extended-producer-responsibility-(epr)-system-for-e-waste-management-system

Niarchos, N. (2021, May 24). *The Dark Side of Congo's Cobalt Rush.* The New Yorker. https://www.newyorker.com/magazine/2021/05/31/the-dark-side-of-congos-cobalt-rush

Nova Scotia Power. (n.d.). *Types of Electric Vehicles.* https://www.nspower.ca/your-home/energy-products/electric-vehicles/types

Next Green Car. (n.d.) *Hybrid Vehicle Emissions.* https://www.nextgreencar.com/hybrid-cars/environmental-benefits/#:~:text=When%20in%20hybrid%20mode%2C%20most,from%20hybridising%20the%20drive%2Dtrain.

Nieuwenhuis, P., Cipcigan, L., & Sonder, H. B. (2020). *The electric vehicle revolution.* In Future Energy (pp. 227-243). Elsevier.

Nissan Motor Corporation. (2019, April 11). *Electric vehicle silence may help improve heart health and noise pollution.* Official Asia and Oceania Newsroom. https://asia.nissannews.com/en/releases/electric-vehicle-silence-may-help-improve-heart-health-and-noise-pollution

Pardo-Ferreira, M. C., Torrecilla-García, J. A., Heras-Rosas, C. D. L., & Rubio-Romero, J. C. (2020). *New risk situations related to low noise from electric vehicles: perception of workers as pedestrians and other vehicle drivers*. International journal of environmental research and public health, 17(18), 6701.

Rathore, A. K., & Prasanna, U. R. (2011, November). *Novel snubberless bidirectional ZCS/ZVS current-fed half-bridge isolated Dc/Dc converter for fuel cell vehicles.* In IECON 2011-37th Annual Conference of the IEEE Industrial Electronics Society (pp. 3033-3038). IEEE.

Reuter, B., Schönsteiner, K., Wagner, M., Gleyzes, D., Massier, T., Hamacher, T., & Lienkamp, M. (2014). *Life cycle greenhouse gas analysis for automotive applications—a case study for taxis in Singapore.* International Journal of Smart Grid and Clean Energy, 3(2), 127-134.

Reuters. (2021, January 15). *BMW aims to double fully-electric vehicle sales in 2021*. Reuters. https://www.reuters.com/article/us-autos-bmw-electric-idUSKBN29K1CI

Tan, A. (2021, June 23). *S'pore exploring hydrogen, carbon capture technologies in decarbonisation goal.* The Straits Times. https://www.straitstimes.com/singapore/environment/spore-exploring-hydrogen-carbon-capture-technologies-in-decarbonisation-goal

REFERENCES

Tan, C. (2021, March 5). *Budget debate: No more new diesel cars, taxis in S'pore from 2025.* The Straits Times. https://www.straitstimes.com/singapore/transport/no-more-new-diesel-cars-taxis-from-2025?utm_medium=social&utm_source=telegram&utm_campaign=sttg

The International Council on Clean Transportation. (2020, November 11). *Growing momentum: Global overview of government targets for phasing out sales of new internal combustion engine vehicles.* https://theicct.org/blog/staff/global-ice-phaseout-nov2020

Thomas, N., Sheppard D., Hume, N. (2021, March 12). *The race to scale up green hydrogen.* The Straits Times: Financial Times. https://www.straitstimes.com/opinion/the-race-to-scale-up-green-hydrogen

TES. (2021, March 24). *Southeast Asia's First Battery Recycling Facility Opens in Singapore*. [Press Release]. https://www.tes-amm.com/press-release/southeast-asias-first-battery-recycling-facility-opens-in-singapore

Towards Zero Waste. (n.d.). *Electronic Waste*. https://www.towardszerowaste.gov.sg/ewaste/#:~:text=Singapore%20generates%20about%2060%2C000%20tonnes,technologies%20constantly%20replacing%20old%20ones.

Transport & Environment Organisation. (2020). *UK briefing: The plug-in hybrid con.* https://www.transportenvironment.org/publications/uk-briefing-plug-hybrid-con

United States Environmental Protection Agency. (n.d.). *Green Vehicle Guide*. https://www.epa.gov/greenvehicles/explaining-electric-plug-hybrid-electric-vehicles

Volkswagen. (2020, December 3). *Battery or fuel cell, that is the question.* Volkswagen Newsroom. https://www.volkswagen-newsroom.com/en/stories/battery-or-fuel-cell-that-is-the-question-5868

Wong, P. T. (2021, March 1). *The Big Read: After a decade of fits and starts, it's all systems go for Singapore's electric vehicle dream.* Today Singapore. https://www.channelnewsasia.com/news/singapore/electric-vehicle-ev-adoption-budget-2021-battery-charging-14300510

World Health Organisation. (2018). *Environmental Noise Guidelines for the European Region.* https://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf

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DIFFERENTIAL ASIA PRESENTS

THE ROAD TO ELECTRIC VEHICLES IN SINGAPORE

Part 3
Infrastructure Requirements

INFRASTRUCTURE REQUIREMENTS

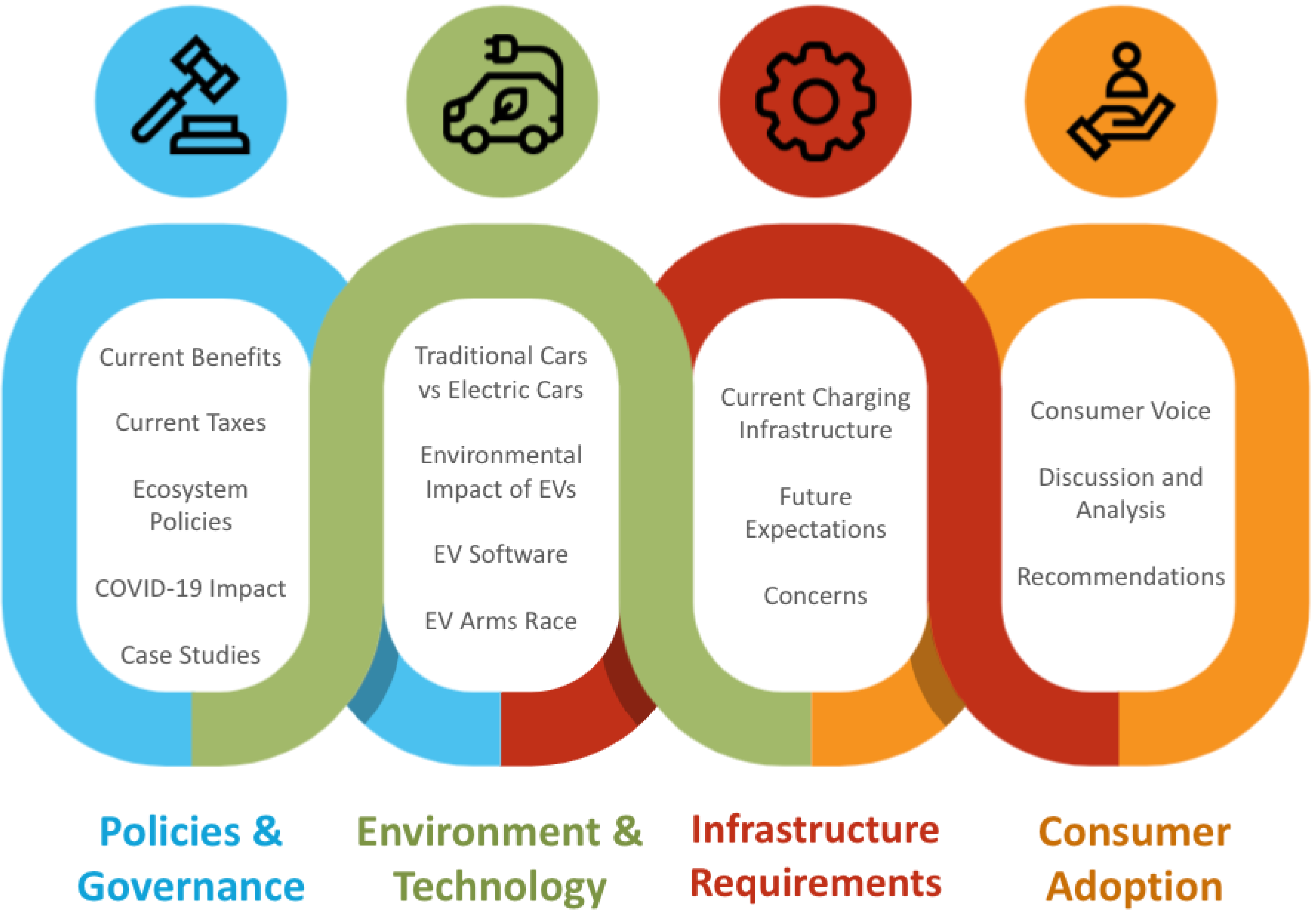
After the previous article's coverage on the environmental impacts of electric vehicles (EVs) and the technological changes in the automotive industry, we take a look at the third dimension of analysis: the status of Singapore's current and future EV charging infrastructure.

differential

Differential Asia is a leading automotive consulting firm that provides advice and recommendations on concerns such as customer centricity and operational effectiveness.
Recognising the increasing relevance of electric vehicles, we decided to compile an educational report on electric vehicles in Singapore to provide a holistic understanding of the local electric vehicle scene.

OVERVIEW

Differential Asia has written four articles regarding the Singapore EV ecosystem, as seen in the image below.



In this chapter, we look at the state of local charging infrastructure, the various concerns regarding charging and other possible methods of refuelling.

CONTENT PAGE

1. CURRENT CHARGING INFRASTRUCTURE IN SINGAPORE

As mentioned in the first article on EV-related Policies and Governance, there are approximately 1,900 electric car charging points in Singapore, with 1,400 of them in public carparks.[1]

These charging points are largely provided by major EV charging service providers such as BlueSG and SP Group, and can be found in areas such as shopping mall carparks or HDB carparks.

Currently, EV owners have to download apps related to the charging network they are using (e.g. download the Greenlots app if they are using Greenlots chargers) to pay for its services. There are numerous charging providers, some of which we have listed for comparison below.

Provider	Charging Type	Charging Time	Number of Stations[2]	Pricing Scheme	Payment	Typical Locations
blueSG	Type 2 AC 3.7kW	A few hours	380+	Monthly subscription and time-based ($0.36/min)	EZ-link / BlueSG card	HDB carparks, open-air URA and LTA carparks
CALTEX[3]	50 kW DC	30 mins	4	46.63 cents/kWh	TBC	Selected Caltex stations
CHARGE+	AC 7.4kW, AC 60kW	A few hours	TBC	TBC	App	Residential, commercial, industrial buildings
greenlots A Member of the Shell Group	AC 7.4kW, AC 22kW, AC 43kW, DC 50kW	30 mins – A few hours	100+	Time-based and per kWh	Greenlots RFID card or app	Malls, offices, hotels, selected Shell stations
Shell Recharge	50 kW DC	30 mins	18	55 cents/kWh	Credit card / Shell Recharge card / Greenlots account	Selected Shell stations
SPgroup	AC 7.4kW, AC 11kW, AC 22kW, AC 43kW, DC 50kW	30 mins – A few hours	54+	40–50 cents/kWh	App	Retail, industrial, commercial, hospitality and tourism properties

Figure 1: EV charging providers in Singapore[4]

1 According to written Parliament reply by then-Minister of Transport Ong Ye Kung, published 1 Feb 2021.
2 There are typically 1-4 charging points per station, depending on the location and provider. Includes both private and public stations.
3 In the process of building
4 Based on BlueSG, Charge+, Greenlots, Shell Singapore websites and EVAS's Singapore EV Guide 2021

2. SINGAPORE STANDARDS FOR CHARGING

Then-Minister of Transport Ong Ye Kung (now Minister for Health) previously announced that Singapore has settled on Type 2 for AC charging and CCS 2 for DC.[5] These are the most widely adopted in the automotive industry. DC charging is also known as fast charging as it charges EV batteries faster than AC due to the former's higher power rating in comparison to the latter.

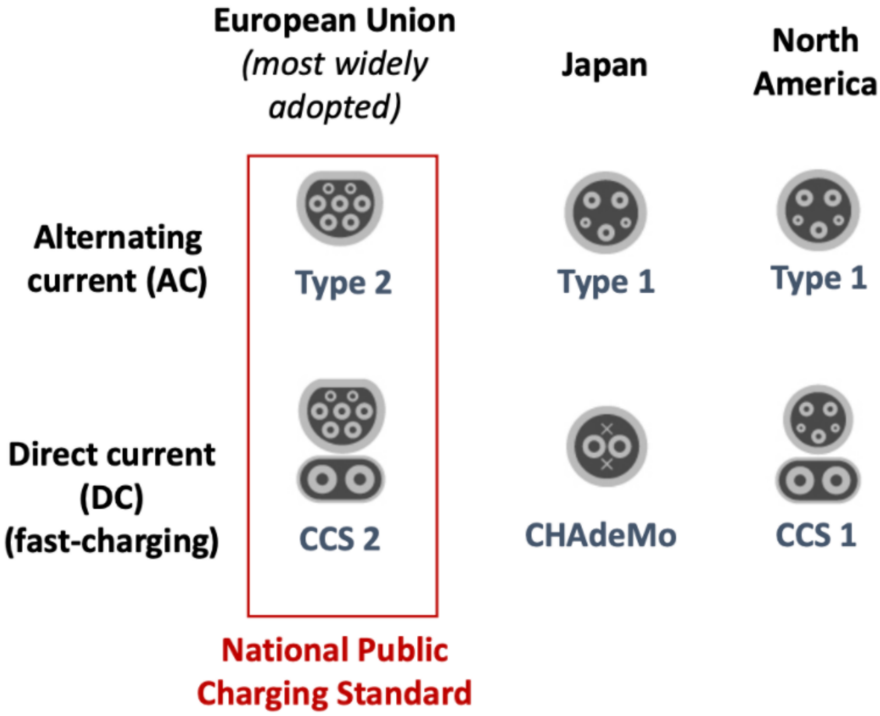


Figure 2: Singapore's public charging standard [6]

In 2020, the Land Transport Authority and the Energy Market Authority announced that the Japanese fast-charging method CHAdeMO (abbreviation of CHArge de MOve) will be considered as an additional public charging standard for EVs as long as it provided Type 2 and Combo 2 connector types, given that all EVs in Singapore must be compatible with such connector types.[7]

5 According to Then-Transport Minister Ong Ye Kung's speech at the Committee of Supply Debate on the Singapore Green Plan 2030, dated 4 March 2021

6 Image credit to Ministry of Transport

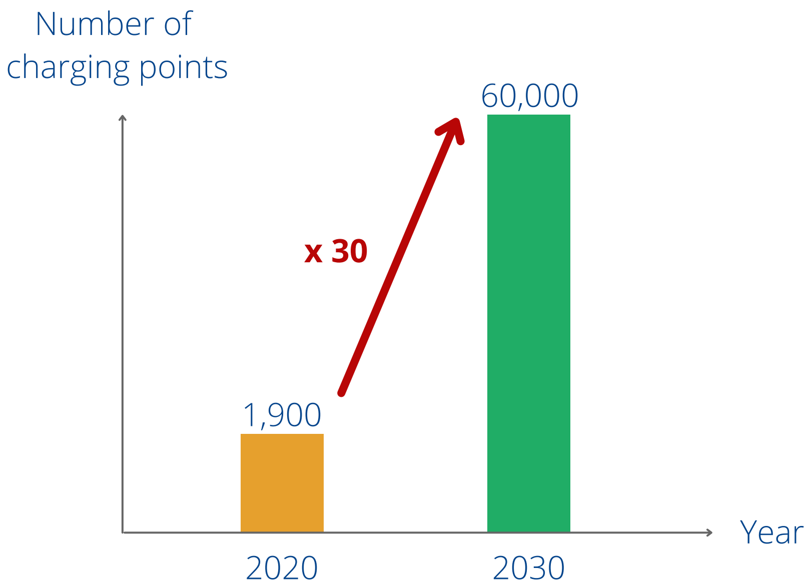
7 According to Energy Market Authority's press release *Addition of CHAdeMO as Optional Public Charging Standard to Support Development of Electric Vehicle Charging Infrastructure,* published 5 March 2020

3. FUTURE CHARGING INFRASTRUCTURE IN SINGAPORE

The following policies are Singapore's targets for her charging infrastructure in the following years.

3.1 SINGAPORE GREEN PLAN 2030

As mentioned in our first article, the government is looking to improve the accessibility of charging infrastructure island wide, with the Singapore Green Plan goal of building 60,000 charging points by 2030. 40,000 charging points will be allocated to public carparks and 20,000 charging points will be allocated to private carparks. This is a thirty-fold increase from our current number of 1,900.



3.2 EV COMMON CHARGER GRANT[9]

LTA is introducing the EV Common Charger Grant (ECCG) from July 2021 to December 2023 (or until 2,000 chargers have been approved for funding) to help the expansion of shared charging infrastructure in existing non-landed private residences (NLPRs) such as condominiums. The ECCG will co-found the installation of 2,000 chargers in such residences, subject to an overall cap of $4,000 per charger. Only installation of chargers with smart charging functions will be co-funded so as to help energy planning and more efficient electricity consumption.

EV charging operators or owners of the residence can apply for the grant to cover three upfront costs: the charging system, the licensed electrical worker fees and cabling and installation costs (subject to a $1,000 cap). The ECCG will co-fund 50% of these components.

According to LTA, the ECCG is designed to catalyse the initial deployment of chargers in as many NLPRs as possible. Hence, the ECCG will only fund the installation of chargers for up to 1% of residential parking lots within each NLPR.

[8] According to LTA news release *Encouraging EV Charger Installation in Non-Landed Private Residences*, published 19 July 2021

3.3 8 EV-READY TOWNS BY 2025

The Housing Development Board (HDB) carparks in 8 towns (Ang Mo Kio, Bedok, Chua Chu Kang, Jurong West, Punggol, Queenstown, Sembawang and the upcoming Tengah town) will have charging points for EVs by 2025. These towns have been selected based on their high concentration of carparks with existing electrical capacity to support the increase in charging infrastructure, and are also spread across Singapore (picture below).

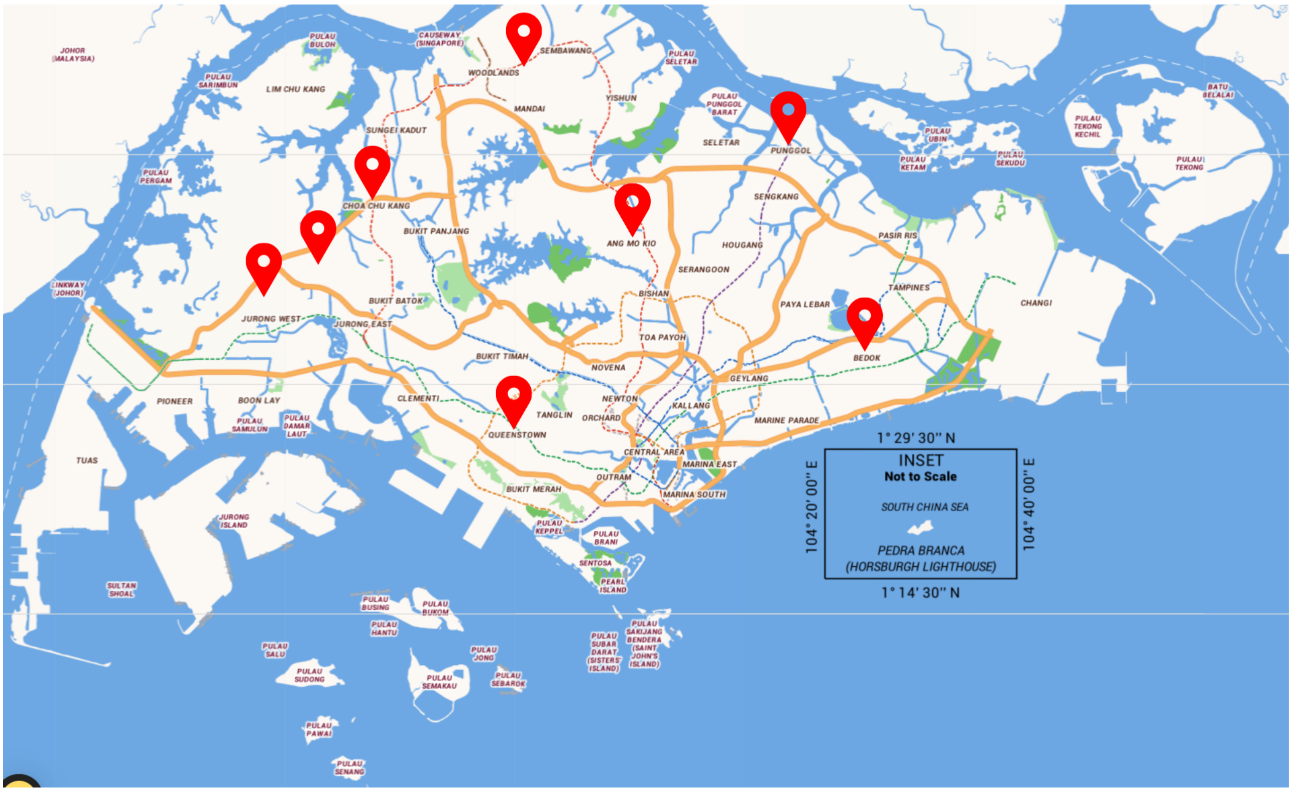


Figure 3: Map of EV-Ready HDB Towns, map credits to OneMap.gov.sg

The Land Transport Authority (LTA) also plans to increase the number and accessibility of charging infrastructure in all towns by the 2030s.[9] All new HDB carparks will also provide sufficient electrical capacity to support EV slow charging for 15% of their parking lots, and a minimum number of chargers will be installed in those lots. Such requirements will be imposed in the future on new private buildings, and those undergoing major redevelopment. More details regarding these requirements will be released by LTA at a later date.

9 According to LTA factsheet, published 4 March 2021

4. CHARGING CONCERNS

There are several concerns surrounding EV charging. While refuelling ICE (internal combustion engine) vehicles is relatively fast and convenient, increasing accessibility of EV charging infrastructure is still underway. Differential Asia has compiled some of the primary concerns below.

4.1 SAFETY CONCERNS

EVs are sometimes deemed “safer” in comparison to ICE vehicles as they do not have an internal combustion engine, which reduces the risks of flammable liquid fuels exploding or catching fire. However, it would be wrong to then assume that EVs have a lower risk profile than ICE vehicles. Lithium-ion batteries tend to have a bad reputation; we have all heard the news of devices being recalled, or of vehicles catching into flames while charging. While lithium-ion batteries are combustible, manufacturers have taken this into account and have equipped EVs with a Battery Management System (BMS) which constantly monitors battery temperature and ensures optimal operation. EV batteries also typically have their own cooling system to prevent high temperatures when functioning.

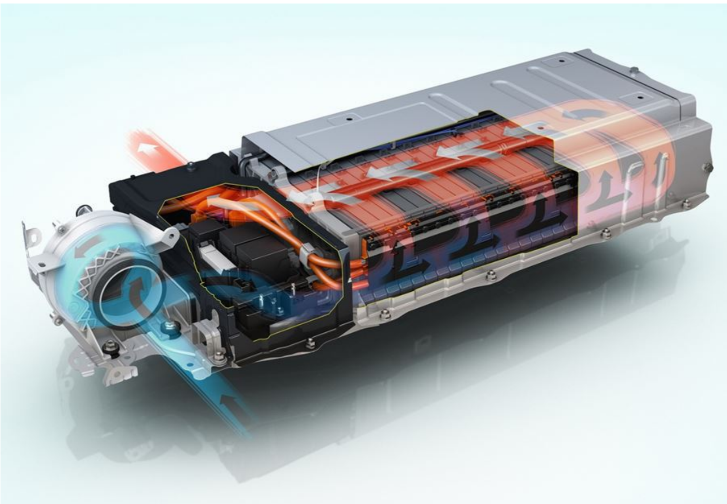


Figure 4: Air cooler battery thermal management system used in the Toyota Prius [10]

Nonetheless, a lot more research needs to be done to check on EV safety standards and performance; this would help to refine our charging and electric grid standards. It would also help format firefighting countermeasures for an EV fire since there may be limited knowledge regarding emissions from battery fire incidents.

LTA is currently leading a comprehensive review of the technical and safety standards governing EV charging in Singapore (known as TR25, or Technical Reference 25) with industry experts and other stakeholders. This review will be completed by the end of 2021. Furthermore, EV charging systems have to pass the mandatory safety technical requirements known as the TR25:2016, the Code of Practice for Electrical Installation and the relevant International Electrotechnical Commission standards to protect persons and properties against electrical hazards.[9]

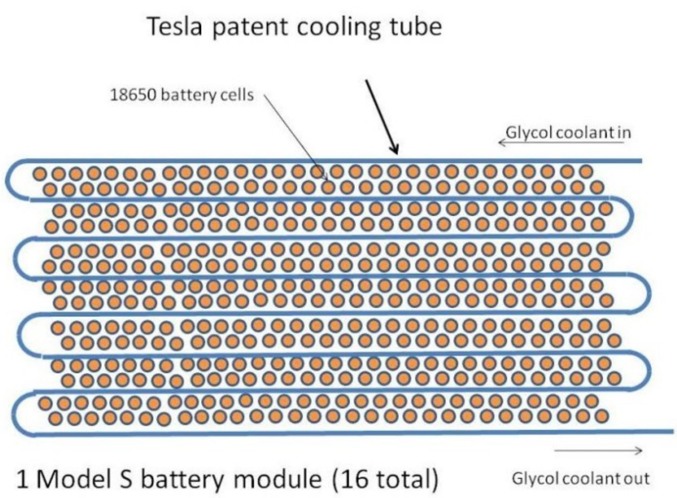


Figure 5: Tesla's metallic cooling tube [11]

[10] Image credits to Toyota

[11] Image credits to InsideEvs.com

4.2 OVERTAXING THE GRID

With no new registrations of ICE vehicles from 2025, and the eventual shift to EVs, the question of how Singapore's electricity grid would manage is one that is often discussed.

Dr Tan See Leng, the Second Minister for Trade and Industry, announced in March 2021 that the electricity grid will be expanded and upgraded to accommodate increased use of EVs in the coming years. The upgrading will be spaced out as Singapore still has a few years before there is a need for such upgraded equipment.

The government will focus on building slow chargers as fast chargers would require a large-scale upgrade of almost all power substations and grid infrastructure. Fast chargers would only be built where the infrastructure is able to support it, or if it is located in an area that is due for an upgrade.

Furthermore, energy supplier SP Group will trial vehicle-to-grid (V2G) technology as an alternative method to support the grid. V2G technology allows energy transfer between EV batteries and the power grid; EV owners can sell their excess energy back to the grid. This would ideally help to balance fluctuations in energy demand, production and consumption, and help Singapore cope with upgrading the electricity grid in anticipation of the growing EV population. Four V2G charging points will be located at SP's premises for the trial, which will be conducted with two units of the Nissan Leaf car, the only V2G-enabled model in Singapore as of today. The trial will be completed in June 2022.

Figure 6: Mr Jimmy Khoo, CEO of SP PowerGrid, with the Nissan Leaf and V2G bidirectional charger that will be used in Singapore's V2G trial [12]

Hence, Singapore's electricity grid is largely well-equipped for mass adoption of EVs.

[12] Image credit to SP Group Press Release, published 8 July 2021

4.3 ACCESSIBILITY CONCERNS

The target of 60,000 charging points island wide by 2030 means approximately 2 or 3 cars per charging point. Industry optimum ratio between EVs and charging points range from 5 to 10 vehicles per point, so Singapore seems to be well on track to building a rather accessible charging network. However, there are some concerns regarding the possibility of meeting such targets given the slowdown in construction due to COVID-19.

For instance, some EV charging providers were not able to hit their 2020 charging infrastructure targets due to delays caused by COVID-19. BlueSG hoped to have 2,000 charging points by the end of 2020, but only had around 1,523 by the deadline.[13] However, as COVID-19 becomes endemic in Singapore, and construction restrictions ease, we can expect such targets to be more achievable.

Unlike conventional fuels which require minutes to refuel, EV batteries take relatively longer to charge. Even with fast-charging, charging a battery from 0 to 80% would take 30 minutes, and slow-charging takes 4 to 7 hours.[14]

The long time taken for recharging, coupled with the fact that most chargers have to be shared, might be a cause for concern for current and potential EV users. Users have to find ways to adapt to integrate such long recharging times into their daily routines; they can choose to charge overnight, like how we charge our phones overnight, or choose to go for a meal or a movie while waiting for the vehicle to charge in the carpark of a shopping mall. Alternatively, a system can be set in place where owners can book charging slots via an app, and are notified once charging is done. They can also be charged for not unplugging their car if they leave it there after it is fully charged.

Ultimately, the onus is on EV users to give up the charger once they are done recharging so as to minimise others' waiting time.

Figure 7: EV charger offered in CapitaLand mall Singapore [15]

13 According to Channel News Asia article BlueSG, SP Group likely to miss electric vehicle charging infrastructure targets for 2020 published December 10 2020.

14 Industry estimates

15 Image credits to CapitaLand

4.4 RANGE ANXIETY

Then-Minister of Transport Ong Ye Kung estimated that each charge provides the vehicle with 400 to 500km, so a typical EV user would need to charge about once every 5 days. The average annual mileage of a typical Singaporean car is 17,500km,[16] which means the average Singaporean covers around 50km a day. Hence EV users would probably have to charge their vehicles once a week.

Those who frequently travel back and forth between Malaysia and Singapore, be it for work or leisure, may be concerned with the current lack of charging infrastructure in Malaysia.

There are currently around 300[17] electric charging points across Malaysia, with limited repair services available for electric vehicles. This is a cause for concern for drivers who may need to quickly recharge their vehicles, or service them on their trip.

However, most electric charging points in Malaysia are currently located in the more frequently-travelled areas, and there are plans to expand the charging infrastructure to 125,000 by 2030.[18]

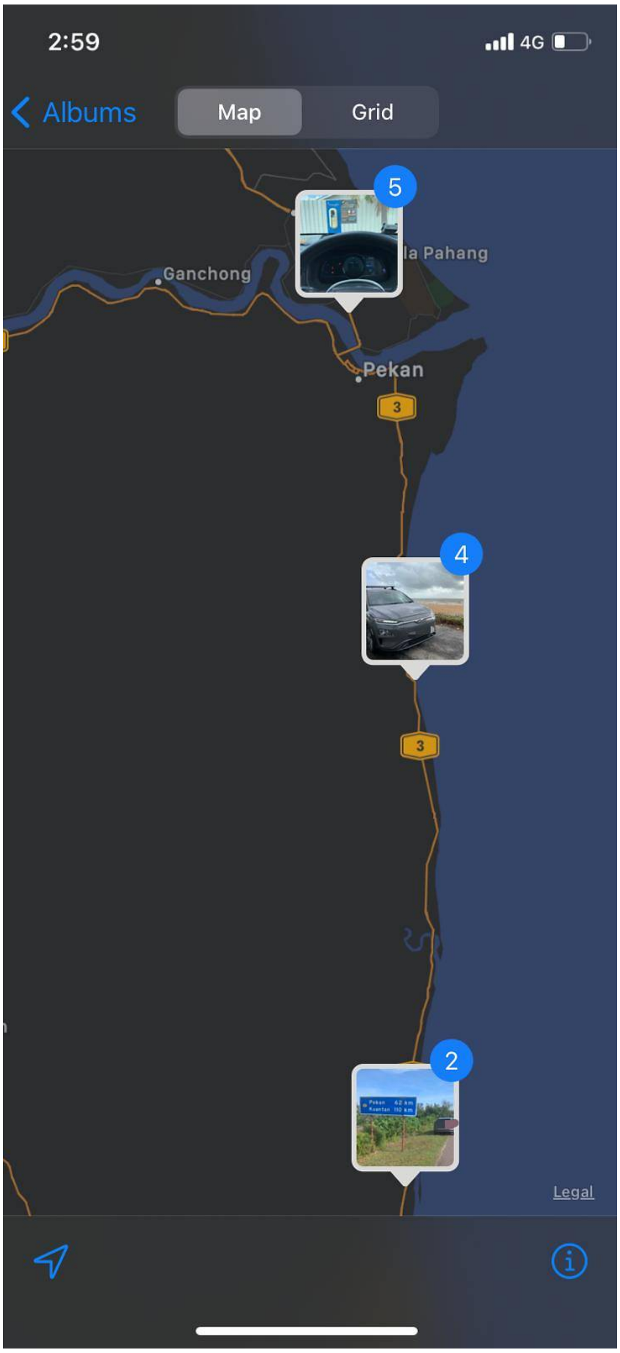


Figure 8: Example of EV driver Koh Jie Ming mapping EV stations in Malaysia[19]

Drivers can hence expect a more convenient trip between Malaysia and Singapore in the coming years. Even drivers who travel frequently between Malaysia and Singapore agree that, currently, it is not that cumbersome to travel with an electric vehicle as long as they plan ahead and keep track of the current charging stations.

16 Based on Data.gov.sg
17 According to Channel News Asia article *Malaysia needs better EV infrastructure to avoid 'anxiety' on road trips, drivers say* published 14 March 2021
18 According to Malaysia's National Electric Mobility Blueprint
19 Image credit to Koh Jie Ming, as seen in Channel News Asia article Malaysia needs better EV infrastructure to avoid 'anxiety' on road trips, drivers say published 14 March 2021

4.5 PAYMENT CONCERNS

The current charging landscape is fragmented — as seen in Figure 1, there are several apps that users can download just to find, use and pay for EV charging. Beep, a Singapore startup, is looking to solve these issues by unifying the payment methods, possibly by QR infrastructure. With this standardisation, payment options possibly will not be as messy in the future.

Users can also use PlugShare, a community-sourced platform where users update charging locations, to find existing charging points across all EV charging providers.

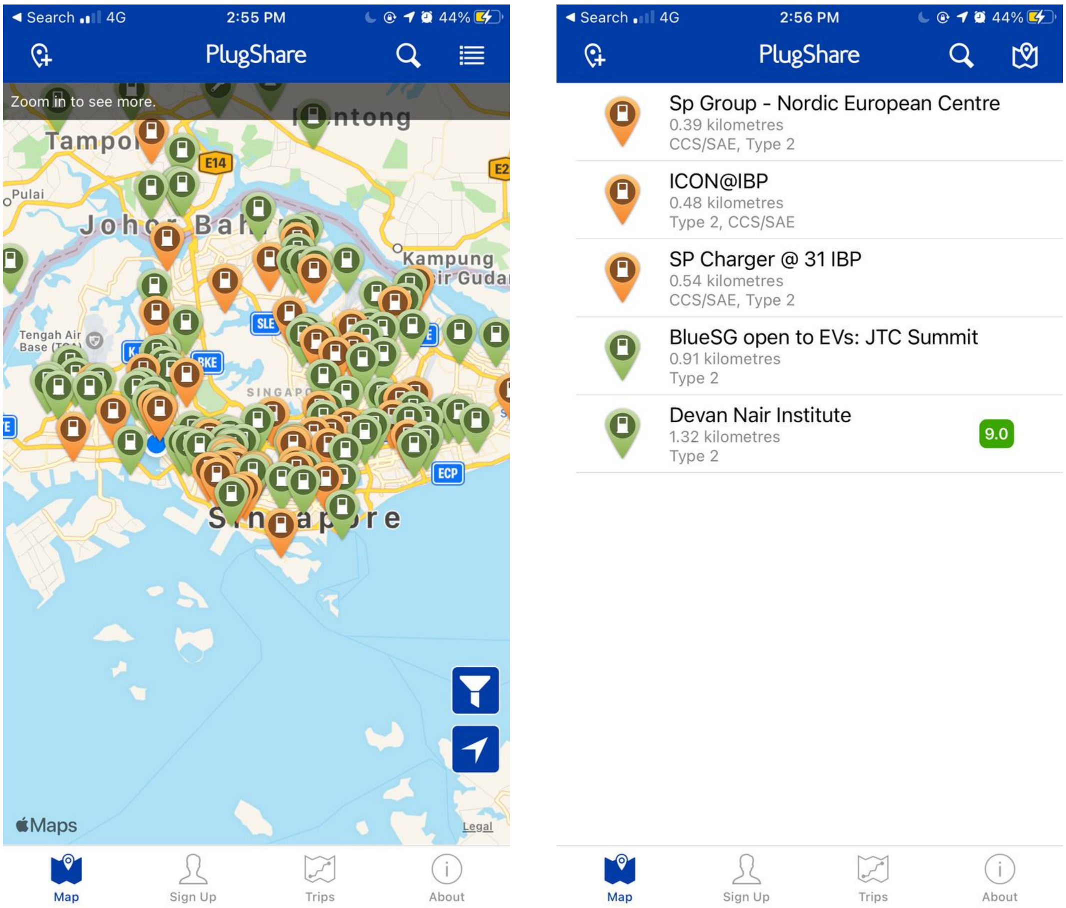


Figure 9: PlugShare app [20]

[20] Screenshots of the app.

5. ALTERNATIVE CHARGING METHODS

There are different methods to charge EVs, although Singapore currently only uses both plug-in slow charging and plug-in fast charging.

5.1 BATTERY SWAPPING

Battery swapping is a technique that involves swapping a depleted electric car battery with one that is fully charged, reducing the time taken to wait for an EV to recharge. This process typically takes up to 5 minutes.

While convenient, battery swap stations have their fair share of cons too. There is no industry agreement to use the same battery across different models of cars. Hence, if we were to build battery swapping stations, we would then require several models of the various battery types at each station. With the average EV battery weighing 500kg, building a battery swap station would be more expensive than building a charging station. Hence, it is more suitable for Singapore to build charging infrastructure instead of battery swapping stations.

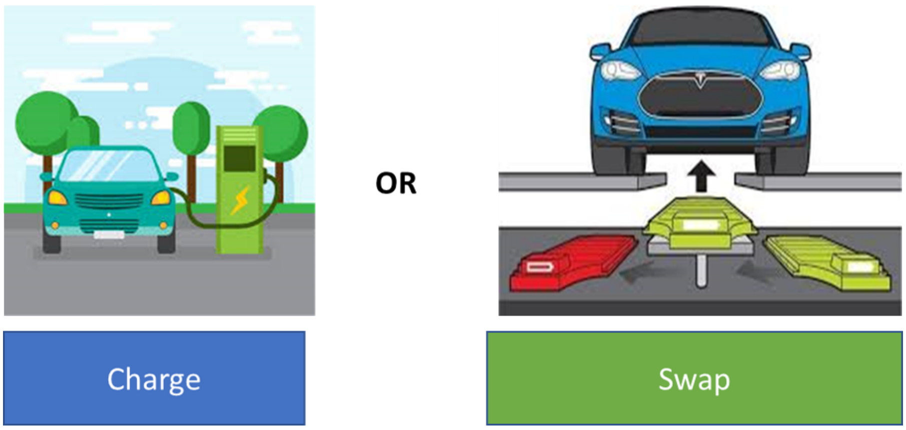


Figure 10: EV Charging vs Battery Swapping [21]

Figure 11: Better Place's battery swap system [22]

[21] Image credit to LinkedIn Article written by Chandana Sasidharan, published 8 February 2020

[22] Image credits to WIRED Article *Better Place Unveils An Electric Car Battery Swap Station* published 13 May 2009

5.2 WIRELESS / DYNAMIC CHARGING

For those who desire an even more convenient method of charging, there is wireless, on-the-go charging for users who wish to charge their EVs while driving. This technology is still largely in the works, with automakers and researchers alike testing out the technology and gathering data.

The process involves implanting wireless charging infrastructure into roads, in which one of the lanes is designated as the "charging lane". All the EV owner has to do is to change lanes to the recharging lane to refuel the battery, before moving back to other lanes, essentially integrating charging while driving. Afterwards, owners will be billed for utilising the dynamic charging. This would solve the issue of limited battery range and long recharging times.

This process is similar to the wireless charging we have for certain appliances.

Figure 12: Samsung's wireless charging[23]

The world's first electrified road that offers dynamic charging was opened in Sweden in 2018. About 2km of electric rail was built into a public road near Stockholm, with plans of expansion in the coming years.[24] People who drive on that particular stretch of road can charge their EVs on the go. Norway, another bellwether country for EV adoption, is also looking at incorporating dynamic charging in their roads in light of increasing use of EVs.

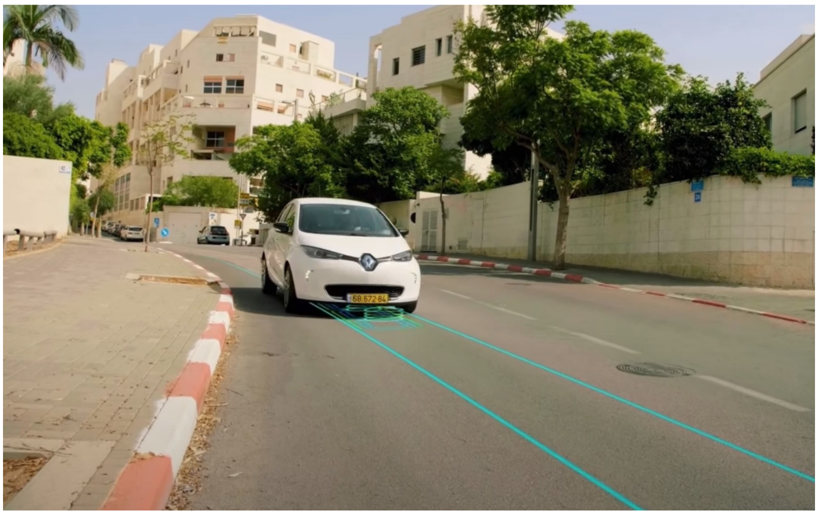


Figure 13: Sweden's dynamic charging[25]

[23] Image credit to Samsung

[24] According to The Guardian article *World's first electrified road for charging vehicles opens in Sweden* published 12 April 2018.

[25] Image credit to Autoevolution article *Sweden Successfully Tests Wireless Charging Road Set to Revolutionise Mobility* published 27 January 2021.

However, dynamic charging is not adopted globally on a large-scale, and the chances of it being adopted in Singapore are even lower. The financial costs are too overwhelming; roads have to be overhauled just to accommodate wireless charging, and it could cost up to USD$2.5 million to electrify a kilometre of a highway.[26]

If implemented in Singapore — a rather faraway dream — it would likely be incorporated into frequently-travelled roads, or along the bus lanes, since public transport would face the most issues with constant recharging.

26 Based on Scania's estimations

6. GLOBAL CHARGING INFRASTRUCTURE

With several countries moving towards adoption of EVs, we can look at their targets for expanding charging infrastructure to better gauge Singapore's progress. The countries listed for comparison in Figure 14 are based on geographical proximity, their political prominence, or their status as bellwether countries for electrification.

	Singapore	Malaysia	Norway	USA	China	UK	Germany	Australia	South Korea	Taiwan
2030 Projected / Target Charging Infrastructure	60,000	125,000	305,000	500,000	8 million	400,000	1 million	NA	500,000 (by 2025)	10,000
2030 Projected Population[27]	4.2 million	23 million	3.6 million	215 million	975 million	43 million	51.9 million	19.5 million	37.4 million (by 2025)	16 million
Density (number of charging points per thousand people)	14.3	5.4	85	2.3	8.2	9.3	19.3	NA	13.4	0.763
2030 Projected EV Population	0.14 million	No clear goal	1.9 million	18.7 million	50 million	18 million	10 million	3 million	2.83 million (by 2025)	NA
Density (number of EVs per charging point)	2.36	NA	6.22	37.4	6.25	45	10	NA	5.66	NA

Figure 14: Comparison of charging infrastructure and density among countries[28]

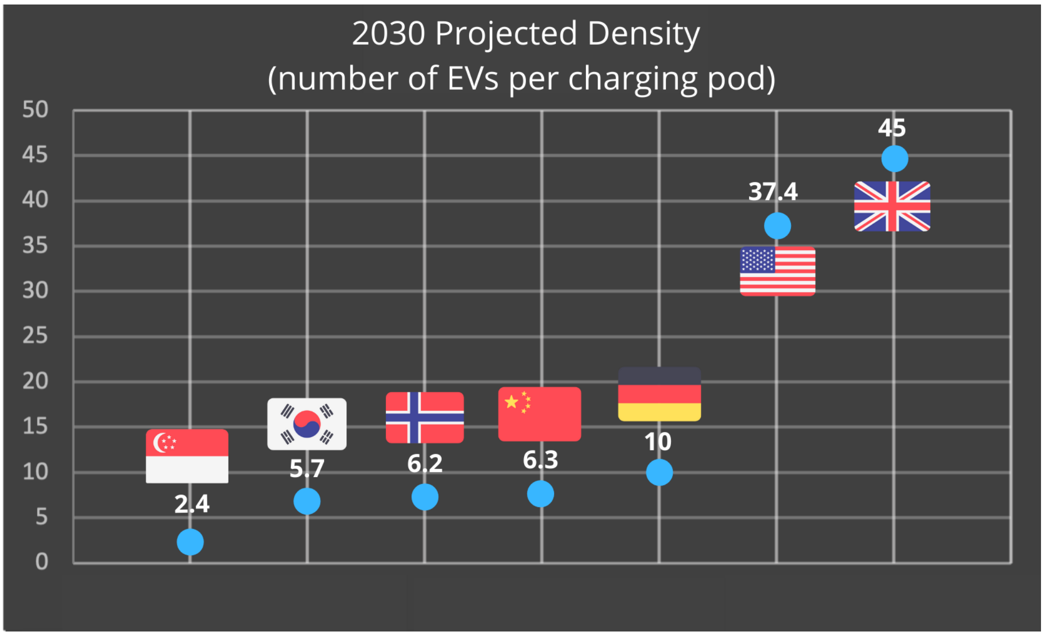


Figure 15: Density plot of number of EVs per charging point across countries in 2030[29]

[27] South Korea's data is from 2025: there are no clear 2030 goals

[28] Based off EuroMonitor data and projections, age group of 20 to 69 years (the age group that is likely to have a driver's license or own or drive a vehicle).

[29] Rounded to 1 decimal place

Another potential roadblock to increasing local consumer demand for EVs could be the lack of accessible charging infrastructure in Malaysia. Their National Automotive Policy 2020 generally lacks clear goals and milestones for the move towards electrification of transport, though this could be attributed to various reasons such as insufficient human capital to support the EV industry.

However, some drivers who frequently travel between Singapore and Malaysia have stated that there is no real concern over charging infrastructure as the mileage of an electric vehicle on a full charge is typically sufficient to cover the distance between Singapore and Malaysia, and even then, several charging infrastructures have been concentrated in the more frequently travelled areas of Malaysia. Furthermore, as seen in Figure 14, Malaysia intends on hitting a target of 125,000 charging stations by 2030 ,[30] which would benefit drivers who frequently travel between Malaysia and Singapore.

Singapore seems to be relatively on track in terms of expanding her charging infrastructure; as seen in Figure 15, she has approximately 2.4 EVs to a single charger. While this number is low, especially in comparison to other countries, only time will tell us whether consumers find these chargers convenient to locate and use. Consumers also have to be responsible enough to let other people use the charger once their own vehicle is fully charged. Hence, while we plan on expanding the infrastructure, we also need to pay attention to charging patterns to identify peak periods and to find ways to ensure that users do not have to compete for chargers.

[30] According to Malaysia's National Electric Mobility Blueprint

7. CONCLUSION

Although the local EV charging infrastructure seems rather promising in terms of accessibility and safety, Singaporeans' level of comfort with using EV charging ultimately depends on whether they can integrate overnight or slow charging into their daily routines. This also depends on the government's progress with building the EV structure in the coming years, and if we do manage to meet our target of 60,000 charging points by 2030. Despite slow charging taking up a few hours, building charging stations is ultimately the most sensible and economical solution for Singapore in comparison to other recharging alternatives. Furthermore, our electrical grid will be able to cope with the impending increase in EV population. Research is being done in preparation to upgrade the grid, as well as to find ways to incorporate V2G technology to help balance demand and supply of electricity. To ensure ease of use for everyone, EV owners have to keep charging etiquette in mind and unplug their cars once the charging process is complete so that it is convenient for others to use after them.

While Singapore seems to be on the path to having an accessible charging infrastructure, close attention has to be paid to charging patterns and electricity usage to ensure that EV users are comfortable with the charging infrastructure.

REFERENCES

Abdullah, Z. (2021, March 4). All HDB car parks in at least 8 towns to have electric vehicle charging points by 2025. Channel News Asia. https://www.channelnewsasia.com/news/singapore/electric-vehicle-charging-points-hdb-carparks-8-towns-14326528

Baker Institute. (2021, January 21). Electric Vehicles: A Small Window for Safety and Stability, a Large Arena for Research. Forbes. https://www.forbes.com/sites/thebakersinstitute/2021/01/21/electric-vehicles-a-small-window-for-safety-and-stability-a-large-arena-for-research/?sh=6f6544996f34

Boffey, D. (2018, April 12). World’s first electrified road for charging vehicles opens in Sweden. The Guardian. https://www.theguardian.com/environment/2018/apr/12/worlds-first-electrified-road-for-charging-vehicles-opens-in-sweden

Channel News Asia. (2020, December 10). BlueSG, SP Group likely to miss electric vehicle charging infrastructure targets for 2020. https://www.channelnewsasia.com/news/singapore/bluesg-sp-group-likely-to-miss-electric-vehicle-charging-13744364

Choo, D. (2021, March 4). S’pore to stop diesel car, taxi registrations, have 8 ‘EV-ready towns’ including Bedok, Punggol, Queenstown by 2025. Channel News Asia. https://www.todayonline.com/singapore/spore-stop-diesel-car-taxi-registrations-8-ev-ready-towns-2025

Data.gov.sg. (n.d.). Annual Mileage for Private Motor Vehicles. https://data.gov.sg/dataset/annual-mileage-for-private-motor-vehicles?view_id=fea21992-54d7-4fbc-a8ab-ec4c8b6b4e94&resource_id=7a913480-0de4-45b8-b922-18166d10d7db

Electric Vehicle Association of Singapore. (2021, March). Singapore Electric Vehicle Guide 2021. https://www.evas.org.sg/#ev-guide-2021

Energy Market Authority. (n.d.). Technical Compliance Checklist for Electric Vehicle Charging System. https://www.ema.gov.sg/Technical_Compliance_Checklist_For_EV_Charging_System.aspx

Energy Market Authority. (2020, March 5). Addition of CHAdeMO as Optional Public Charging Standard to Support Development of Electric Vehicle Charging Infrastructure. [Press Release]. https://www.ema.gov.sg/media_release.aspx?news_sid=20200306jJ6ZcqpCMXOU

Hodari, D. (2021, January 18). These Companies Want to Charge Your Electric Vehicle as You Drive. The Wall Street Journal.https://www.wsj.com/articles/these-companies-want-to-charge-your-electric-vehicle-as-you-drive-11610965800

Kay, G. (2021, May 9). *New electric vehicle charging research could allow drivers to power their cars as they drive on the highway.* Business Insider. https://www.businessinsider.com/charge-electric-car-while-driving-technology-cornell-2021-5

REFERENCES

Land Transport Authority. (2021, March 4). *Factsheet: Accelerating Nationwide Deployment of Electric Vehicle Charging Points.* *https://www.lta.gov.sg/content/ltagov/en/newsroom/2021/3/news-release/Accelerating_nationwide_deployment_of_electric_vehicle_charging_points.html#:~:text=Factsheet%3A%20Accelerating%20Nationwide%20Deployment%20of%20Electric%20Vehicle%20Charging%20Points,-News%20Releases%2004&text=The%20Government%20targets%20to%20deploy,and%2020%2C000%20in%20private%20premises.*

Land Transport Authority. (2021, March 4). *Factsheet: Encouraging the Adoption of Electric Cars for a More Sustainable Land Transport Sector.* https://www.lta.gov.sg/content/ltagov/en/newsroom/2021/3/news-release/Encouraging_the_adoption_of_electric_cars.html

Land Transport Authority. (2021, July 19). *Encouraging EV Charger Installation in Non-Landed Private Residences.* *https://www.lta.gov.sg/content/ltagov/en/newsroom/2021/7/news-releases/encouraging-ev-charger-installation-in-non-landed-private-reside.html*

Neo, C. C. & Sim, Y. L. (2021, July 10). *Road trips, battery safety and competing for chargers: 10 electric car queries answered.* Channel News Asia. https://www.channelnewsasia.com/news/cnainsider/road-trips-battery-safety-charging-points-electric-car-questions-15190286

Ng, K. (2021, June 14). *EV agenda draws various sectors vying for slice of the pie.* The Business Times.

Ministry of Transport. (2021, March 4). Speech by Minister for Transport, Mr Ong Ye Kung, at the Committee of Supply Debate 2021 on Singapore Green Plan 2030. https://www.mot.gov.sg/news-centre/news/Detail/speech-by-minister-for-transport-mr-ong-ye-kung-at-the-committee-of-supply-debate-2021-on-singapore-green-plan-2030/

Radu, V. (2021, January 27). *Sweden Successfully Tests Wireless Charging Road Set to Revolutionise Mobility.* Autoevolution. https://www.autoevolution.com/news/sweden-successfully-tests-wireless-charging-road-set-to-revolutionize-mobility-155137.html#

Sasidharan, C. *EV Charging 105: Battery Swapping.* LinkedIn. https://www.linkedin.com/pulse/ev-charging-105-battery-swapping-chandana-sasidharan/

Scania. (2018, August 30). *Scania is part of Europe's first long haul electric truck trials.* https://www.scania.com/uk/en/truckeast/experience/news/2018/08/electric-truck-trials.html

SP Group. (2021, July 8). *SP Group starts trial of vehicle-to-grid integration to pave the way for greater EV adoption.* [Press Release]. https://www.spgroup.com.sg/wcm/connect/spgrp/168a3c1c-b279-46bf-ae1c-fe3d7f6e37fd/%5B20210708%5D+Media+Release+-+SP+Group+starts+trial+of+vehicle-to-grid+integration+to+pave+the+way+for+greater+EV+adoption.pdf?MOD=AJPERES&CVID=

Squatrilga, C. (2009, May 13). *Better Place Unveils an Electric Car Battery Swap Station.* WIRED. https://www.wired.com/2009/05/better-place/

REFERENCES

Tan, C. (2021, March 23). *4 Caltex stations to offer electric vehicle charging points.* The Straits Times. https://www.straitstimes.com/singapore/transport/4-caltex-stations-to-offer-electric-vehicle-charging-points

Wong, P. T. (2021, March 4). *S'pore's electricity grid to be expanded, upgraded to cater for more electric vehicles: Tan See Leng.* TodayOnline. https://www.todayonline.com/singapore/spores-electricity-grid-be-expanded-upgraded-cater-more-electric-vehicles-tan-see-leng

Yusof, A. (2021, March 14). *Malaysia needs better EV infrastructure to avoid 'anxiety' on road trips, drivers say.* Channel News Asia. https://www.channelnewsasia.com/news/asia/malaysia-singapore-transport-electric-cars-ev-range-anxiety-14381688

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DIFFERENTIAL ASIA PRESENTS

THE ROAD TO ELECTRIC VEHICLES IN SINGAPORE

CONSUMER ADOPTION

After the previous article's coverage on the state of electric vehicle (EV) charging infrastructure in Singapore, we now take a look at the fourth pillar of analysis: consumer's concerns regarding purchasing and using EVs.

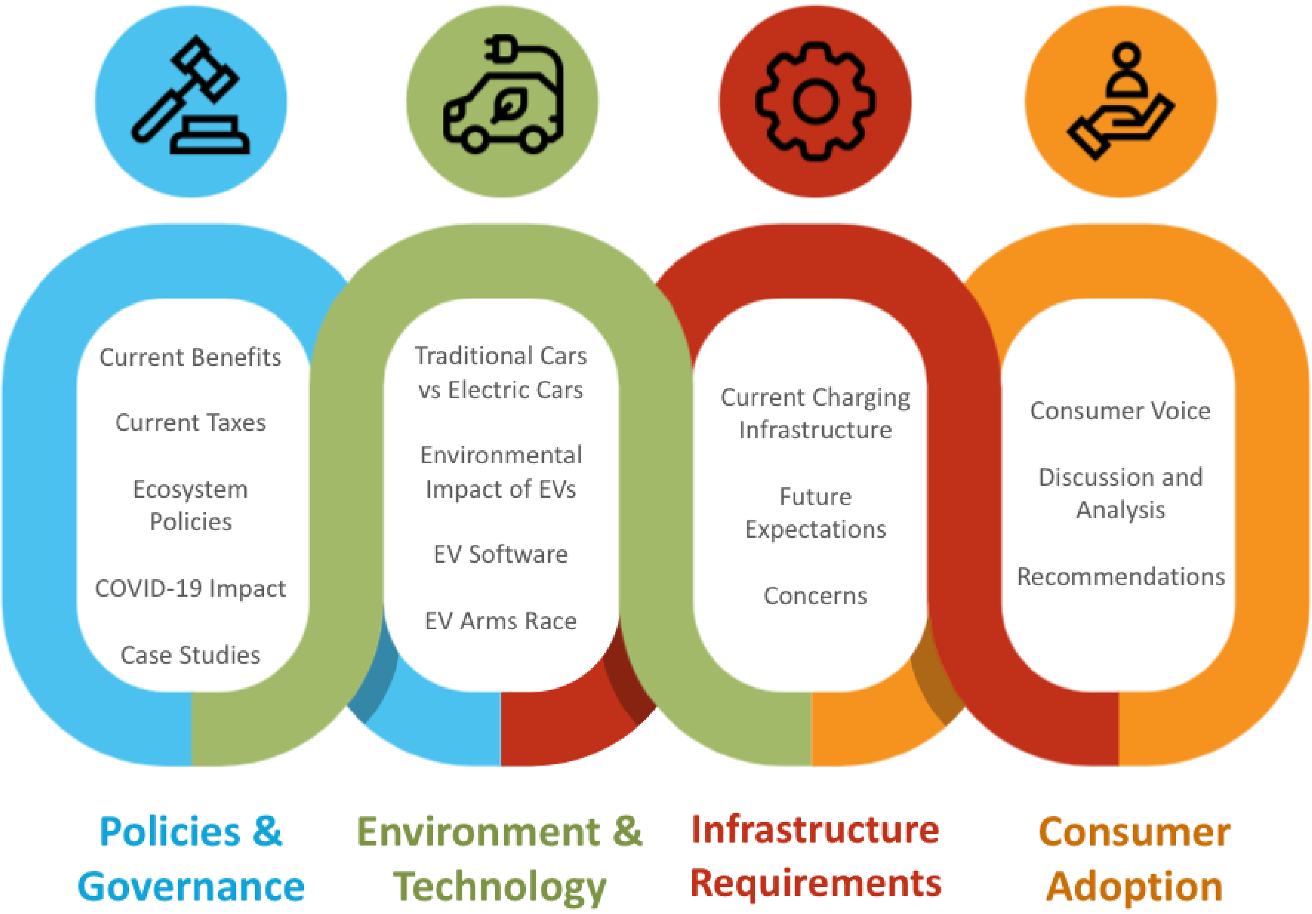
differential

Differential Asia is a leading automotive consulting firm that provides advice and recommendations on concerns such as customer centricity and operational effectiveness.

Recognising the increasing relevance of electric vehicles, we decided to compile an educational report on electric vehicles in Singapore to provide a holistic understanding of the local electric vehicle scene.

OVERVIEW

Differential Asia has written four articles regarding the Singapore EV ecosystem, as seen in the image below.



In this chapter, we look at the various concerns consumers have regarding EV adoption and recommendations to resolve such issues.

CONTENT PAGE

1. CONSUMER CONCERNS: BACKGROUND

Despite measures such as the provision of fiscal incentives and targets of expanding the charging infrastructure, consumers may still have some qualms over EV adoption. In[1] the section below, we compare a survey conducted in 2016 to a survey Differential Asia conducted in 2021 to analyse trends and shifts in consumer perception of EVs. Both surveys were conducted in Singapore.

Differential Asia sent out the survey online from June to July 2021.

[1] In *Public's Perception of Adopting Electric Vehicles: A Case Study of Singapore* by Min Xu, Qiang Meng and Yisi Liu

2. CONSUMER VOICE: PERCEIVED ADVANTAGES OF EVS

Respondents in the 2016 survey ranked the top three advantages of EVs as: fuel saving (61.3%), environmental-friendliness (55.4%) and ability to charge at home (52.5%)[5].

The top three advantages of purchasing an EV from the 2021 survey results were: environmental-friendliness (47.4%), lower maintenance costs than ICE equivalents (26.3%) and price parity with ICE equivalents (10.5%).

Both surveys have similar perceived EV advantages; the environmental benefits that EVs provide as well as the fuel savings, which translates to lower maintenance costs.

2.1 ADVANTAGE OF EVS: ENVIRONMENTAL-FRIENDLINESS

EVs are known to be green vehicles due to their lack of tailpipe emissions. While they do triumph ICE vehicles in this aspect, other factors also have to be considered to accurately judge if EVs are truly green in terms of their overall lifecycle emissions. This means taking into account the source of electricity (is it from a renewable source? Or fossil fuels?), the sourcing of materials, and the disposal of EV batteries.[2]

In the 2021 survey, 83.2% of respondents said that they were "somewhat conscious" of the impact of their day-to-day activities on the environment. As we move towards the green revolution, we can anticipate consumers to become more cognisant of the impact of their purchases on the environment.

[2] Full analysis on how green EVs are can be found in Article 2.

2.2 ADVANTAGE OF EVS: LOWER MAINTENANCE COSTS

EVs do not have an ICE engine. This translates into lower maintenance costs in the long term, given that the vehicle will not have to be serviced for things such as changing the oil or managing the engine.

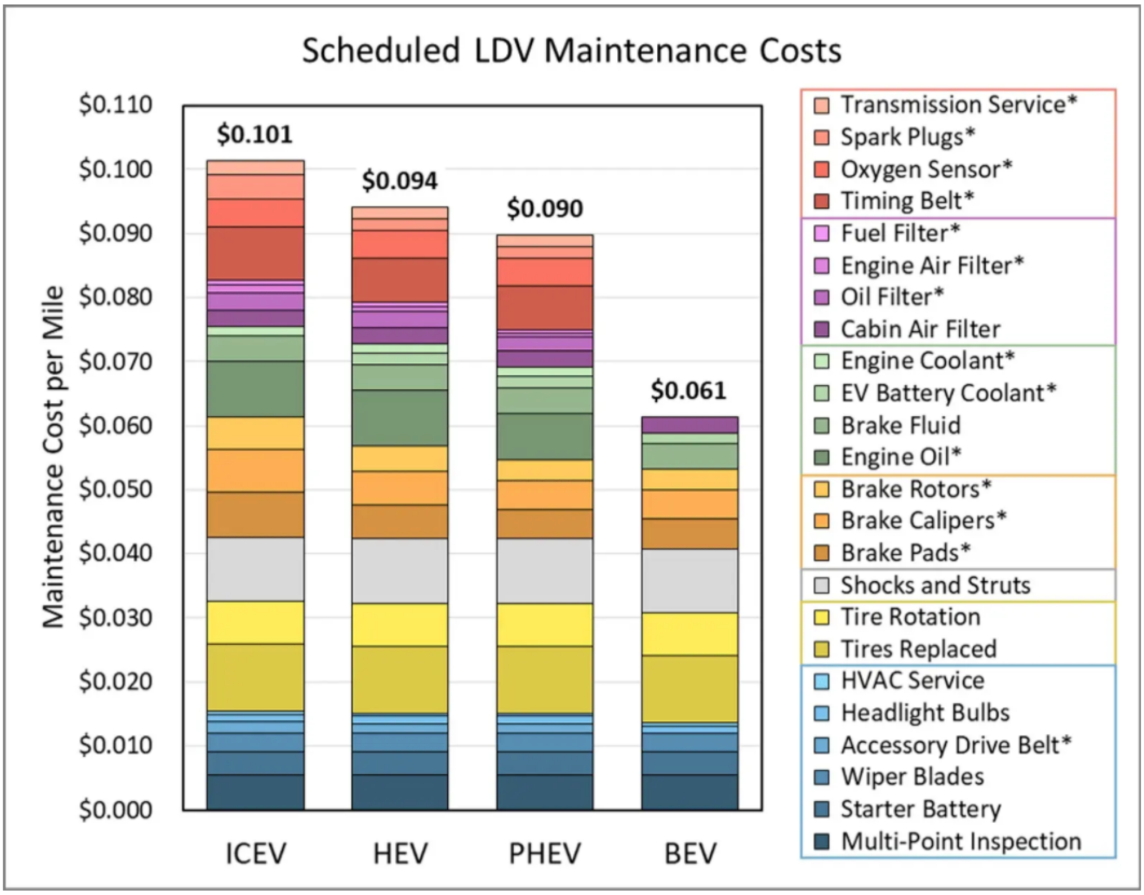


Figure 1: Maintenance costs across ICEVs, HEVs, PHEVs and BEVs [3]

As seen in Figure 1, ICE vehicles have the highest maintenance cost per mile, at USD$0.101, while the various EV types have lower costs, with BEVs enjoying the lowest cost at USD$0.061.

Although some might be concerned over the lifespan of the EV battery, industry estimates place the typical battery lifespan to be around 5 to 10 years, especially with advancements in technology and battery development.

[3] According to LTA news release *Encouraging EV Charger Installation in Non-Landed Private Residences*, published 19 July 2021

2.3 ADVANTAGE OF EVS: PRICE PARITY WITH ICE EQUIVALENTS

There have been numerous fiscal incentives implemented to encourage EV adoption in Singapore.[4] The current price point of EVs are seen both as an advantage and disadvantage (see section 3.3), possibly due to lack of awareness of such fiscal incentives.

31.8% of respondents had heard of the EV Early Adoption Initiative (EEAI), making it the most known EV fiscal incentive, followed by the waiver of the Additional Registration Fee (ARF) at 25% and the Enhanced Vehicular Emissions Scheme (VES) at 20.5%.

However, a larger number of respondents (38.6%) said that they had not heard of any of the fiscal policies or the plans to expand charging infrastructure. Policy awareness has to be raised for consumers to better understand the price parity between ICE vehicles and EVs.

[4] Refer to Article 1 for compilation of all fiscal incentives.

3. CONSUMER VOICE: PERCEIVED DISADVANTAGES OF EVS

The survey conducted in 2016 revealed the top three perceived disadvantages of EVs: its high purchase price (62.3%), its long charging time (30.9%) and its driving range (13.7%). Over 80% of respondents said that they drove less than 55km daily, which explains why range anxiety was the least of their concerns.

50.5% of respondents in the 2021 survey indicated that they drove 500 to 1000km a month, which puts them in the range of driving 17 to 34km a month. When asked to identify the most important concern they had regarding purchasing an EV, the top three concerns that emerged were the lack of charging infrastructure (26.2%), insufficient knowledge on EVs in general (20%) and its high purchase price (15.4%).

3.1 DISADVANTAGE OF EVS: LACK OF CHARGING INFRASTRUCTURE

The top-rated concern of lack of charging infrastructure is rather surprising, considering the target to have 60,000 charging points across Singapore by 2030, a significant increase from the current number of 1,900.[5] When asked about their awareness of EV-related policies, the policy that had the most recognition (50% said they had heard of it) was the plan to have 60,000 charging points island wide by 2040. Despite the awareness of the expansion of charging stations, the accessibility of said chargers remains a prominent concern for local consumers; when asked about the most important factor that would incentivise them to purchase an EV, having more conveniently-located charging stations received the most responses (58.3%).

This reveals consumers' desire for convenience; they want the assurance that chargers will be both ubiquitous and conveniently located such that their daily routines are not inconvenienced as a result of them having to search for a charger. Refuelling stations for ICE vehicles are widespread and consumers need to only take a few minutes to refill the tank. It is no wonder then that consumers are worried about how the shift to EVs may be more inconvenient than their usual routine with ICE vehicles.

With the government planning to support deployment of EV chargers in both HDBs and non-landed private residences (e.g. condominiums), and companies such as SP Group also rolling out more EV chargers, chargers are expected to become more accessible in the future.

[5] According to written Parliament reply by then-Minister of Transport Ong Ye Kung, published 1 Feb 2021.

3.2 DISADVANTAGE OF EVS: INSUFFICIENT KNOWLEDGE ON EVS

The switch to EVs may be intimidating to those who are more used to ICE vehicles, especially since there are currently more ICE vehicle models available in the market in comparison to EVs.

When asked to judge their knowledge on EVs, the most common response in the 2021 survey was "I barely know anything about EVs" (48.3%). Only 19.3% of respondents had driven an EV,[6] and an even smaller minority of 2.3% owned an electric vehicle.

While lack of knowledge on EVs may slow down EV adoption, as EVs begin to permeate the automotive industry and ICE vehicles are phased out on a global scale,[7] consumers will naturally learn more about EVs, and become more comfortable with the notion of buying them. Furthermore, the switch to EVs is a compulsory one; consumers have to learn to adapt to using cleaner vehicles, though in Singapore, we might see more consumers purchasing hybrids over EVs should their lack of knowledge on EVs be such a significant concern to them.

3.3 DISADVANTAGE OF EVS: HIGH PURCHASE PRICE

The decrease in people viewing high purchase price as a disadvantage of EVs can be attributed to announcements made in Budget 2020[8] to introduce fiscal incentives to help EVs achieve price parity with ICE vehicles (e.g. EV Early Adoption Incentive, revised Vehicular Emissions Scheme etc).[9]

While EVs are expected to reach price parity with ICE vehicles in 2025 to 2027, EV adoption would still be slower in Singapore, given the high taxes imposed on vehicles.[10]

[6] Including car-sharing vehicles such as BlueSG

[7] Refer to Articles 1 and 2 to see a timeline of global and OEM electrification targets.

[8] According to LTA's News Release *Supporting Cleaner and Greener Vehicles for A Sustainable Land Transport Sector*, published 18 February 2020.

[9] More information on EV-related policies can be found in our first article in this series.

[10] More analysis on this can be found in Article 1.

3.4 DISADVANTAGE OF EVS: RANGE ANXIETY

Range anxiety may no longer be as prominent of a concern with the average range of EVs improving in the past years. In 2016, the average EV had a battery range of about 135km per charge. Now, the average EV battery range has increased to about 300km per charge. This is more than a twofold increase in 5 years. As OEMs become more competitive and seek to improve EV battery capacity, future EV models are expected to have greater ranges in the near future (e.g. the Tesla Roadster, available from 2022, has a range of 970km, and the upcoming Mercedes EQS 450+ will have a range of 640km).[11] This likely increased consumer confidence in EV range.

Figure 2: Tesla Roadster (left) and Mercedes EQS 450+ (right) [12]

[11] According to the Electric Vehicle Database.

[12] Image credit to Tesla and Mercedes Benz.

4. CONSUMERS' OEM IMPRESSIONS

How much do consumers know about OEMs and their electrification targets?

The 2021 survey asked respondents to rate various car brands[13] on how environmentally friendly they thought they were.

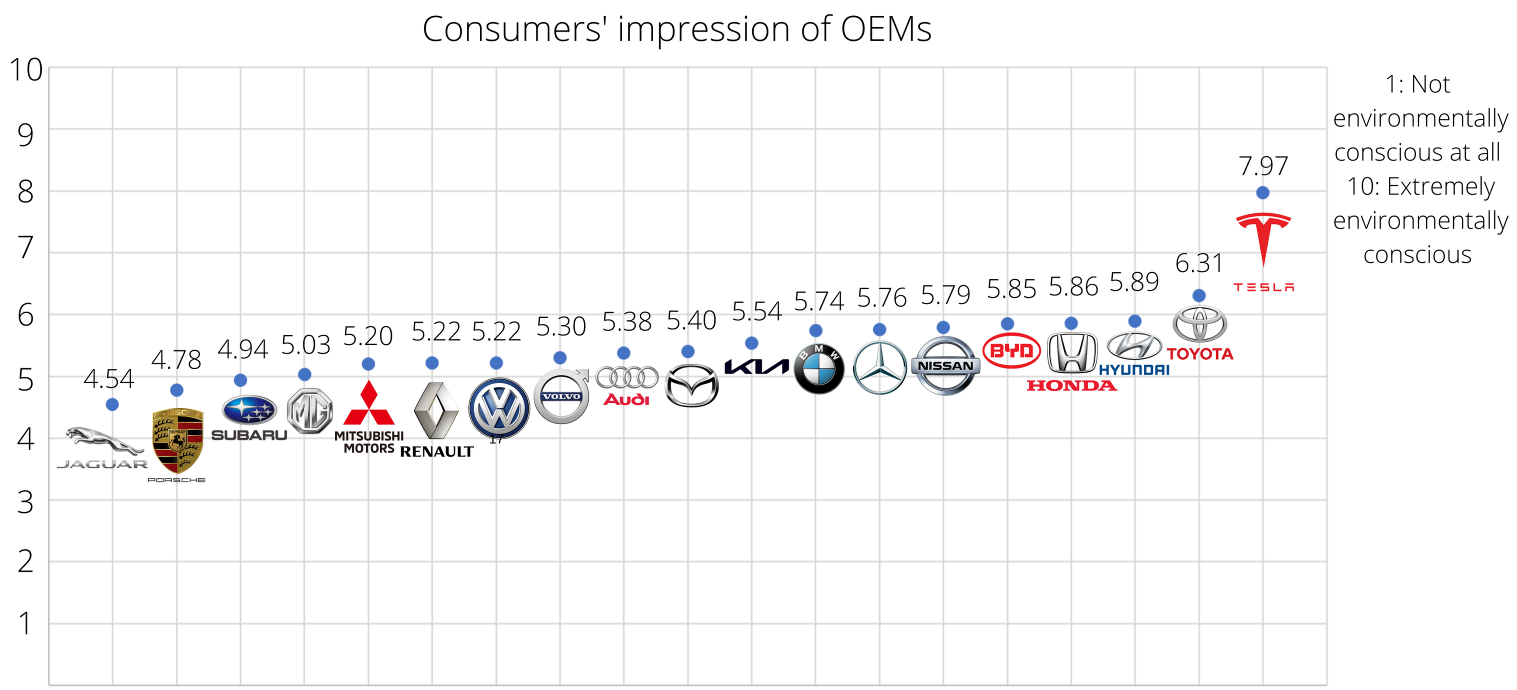


Figure 3: Consumer's impression of how environmentally-friendly OEMs are

As seen in Figure 3, cars typically known for their sports cars tend to be rated lower, while Tesla is rated as the most environmentally friendly, although this might be due to the fact that Tesla manufactures EVs and not ICE vehicles.

While OEMs shift to manufacturing EVs over ICE vehicles, attention has to be paid to their electrification targets, as well as how green their manufacturing processes are.

[12] This is not an exhaustive list. Companies were chosen based off top 10 car makers with highest vehicle population in Singapore, as well as OEMs that are known for manufacturing EVs.

5. THE ROLE OF CONSUMERS

As previously outlined, EVs are not necessarily carbon neutral nor entirely environmentally friendly — there are multiple factors to take into account beyond just their tailpipe emissions. The responsibility of being environmentally friendly is a shared one; as individuals, we cannot rely purely on government policies to keep our carbon footprint in check.

While consumers have to buy cleaner vehicles in the future, the greenest mode of transport is public transport, and the government has been working on making public transport more accessible for everyone. Nonetheless, this ultimately depends on consumers' mindset towards using public transport. Public transport may not be preferable for certain consumers, i.e. those with large families.

Once EV adoption is well underway, consumers also need to get used to slow charging, since the government intends for the majority of chargers to be slow chargers, since upgrading the grid to accommodate fast charging would be too costly.

As the world changes, and Singapore follows suit, it is up to consumers to change alongside everyone else and adapt to the world of greener vehicles and fuel.

6. RECOMMENDATIONS

To help consumers adjust to EVs, and to adapt to slow charging, current EV pricing rebates and related policies can be promoted more. As pricing policies are implemented over the coming years, vehicle consumption patterns have to be watched to determine if pricing policies should change in the future to encourage EV adoption, especially considering the taxes imposed on vehicles in Singapore. However, as EVs reach price parity with ICE vehicles by 2025 to 2027, ideally, more consumers would shift to EVs and government rebate can be somewhat reduced and channelled into other EV-related policies.

Electricity consumption patterns also have to be observed to see if there is a need to adjust our charging infrastructure targets, or whether more upscaling of the grid is necessary. A payment system can also be set in place to charge users who leave their vehicles in the charging station despite having already charged their batteries to ensure that other users do not have to wait too long for their turn.

7. CONCLUSION

EVs should become the ideal vehicular choice for consumers, given their perceived benefits such as their environmental-friendliness, lower maintenance costs and approaching price parity with ICE vehicles. Ultimately, consumers are price-driven; as long as the upfront and long-term costs of EVs are lower than that of ICE vehicles, the will to switch will manifest.

However, consumers may have some qualms over using EVs — they are worried about accessibility of EV chargers, high purchase price and generally feel that they do not know enough about EVs to be willing to use it in the long term. While price parity (without government rebates) is on the horizon, consumers may not be aware of current fiscal incentives to purchase EVs. Hence, more policy awareness should be raised in this period of time. While Singapore seems on track to building a rather ubiquitous charging infrastructure, consumers' response to the expanding infrastructure has to be monitored to see if it is truly accessible for them. Consumers also have to adapt to slow charging and practice charging etiquette for EV chargers to be convenient for everyone.

OEMs also play a role in our road towards transport electrification; with more EV models expected to join the market in the nearing years, we can expect consumers to be more comfortable with the idea of purchasing EVs given a variety of choices. Nonetheless, OEMs have to ensure that the manufacturing process and battery disposal is done in a sustainable manner to ensure that EVs are really the "greener" alternative.

As with most large-scale changes, the shift to EVs is one that requires the effort of various stakeholders and perspectives. In these four articles that make up the series of The Road to Electric Vehicles to Singapore, Differential Asia has outlined the relevant stakeholders and pillars of analysis to consider as transport electrification becomes an imminent reality. We hope that they have helped you understand the current and future EV landscape in Singapore.

REFERENCES

Electric Vehicle Database. (n.d.). *All electric vehicles.* https://ev-database.org/#sort:path~type~order=.erange_real~number~desc|range-slider-range:prev~next=0~1200|range-slider-acceleration:prev~next=2~23|range-slider-topspeed:prev~next=110~450|range-slider-battery:prev~next=10~200|range-slider-eff:prev~next=100~300|range-slider-fastcharge:prev~next=0~1500|paging:currentPage=0|paging:number=9

Land Transport Authority. (2020, February 18). *Supporting Cleaner and Greener Vehicles for A Sustainable Land Transport Sector*. https://www.lta.gov.sg/content/ltagov/en/newsroom/2020/2/news-releases/Supporting_cleaner_and_greener_vehicles.html

Shahan, Z. (2021, June 29). *Electric Vehicles Have Much Lower Maintenance Costs*. CleanTechnica. https://cleantechnica.com/2021/06/29/electric-vehicles-have-much-lower-maintenance-costs/

Xu, M., Meng, Q., & Liu, Y. (2017). *Public's perception of adopting electric vehicles: a case study of Singapore*. Journal of the Eastern Asia Society for Transportation Studies, 12, 285-298. https://www.jstage.jst.go.jp/article/easts/12/0/12_285/_pdf/-char/en

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