ELECTRICITY DEMAND IN RELATION TO RISE OF ELECTRIC VEHICLES IN MALAYSIA

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ABSTRACT

The demand for electric vehicles (EV) is increasing rapidly in advanced countries due to various factors. With increasing number of fully electric or plug-in hybrid vehicles, the demand for electricity in relation to rise of EV in Malaysia must be established. This will affect the built environment as far as electricity infrastructure is concerned. A quantitative correlation method is used to research the key factors affecting the number of EV against the electricity demand in Malaysia. This research mainly is to indicate the strengths and weaknesses in the existing system. It will provide action points for the relevant government entities and/or private sector to act on. This research is essential for Malaysia to be prepared to face the phenomenon that could take our nation by storm. The strategic directions to overcome challenges that are considered in this research encompass several aspects which will need to work in tandem.

Key words: EV, electricity demand, correlation, sustainable transport

INTRODUCTION

Electric Mobility generally refers to the use of electric vehicles (EVs) in road transportation. This includes buses, cars, vans, lorries, scooters and motorcycles for public and private transportation. Electric Mobility promotes the conservation of the natural environment and resources, with zero CO2 tailpipe emissions from battery electric vehicles (BEV), providing a safer, cleaner, smarter and more efficient mode of transportation for the nation [1].

Electric Vehicles (EVs) are defined as vehicles with two or more wheels whose main powertrain comprises of one or more electric traction motors powered using energy stored in batteries, requiring charging of the batteries from external electric power supply through a vehicle inlet socket. The vehicles must conform to UNECE R100 (safety requirements), UNECE R101 (energy consumption), and UNECE R85 (measurement of electric drive power). The range of EVs includes the likes of plug-in hybrid electric vehicle (PHEVs) and battery electric vehicle (BEVs). Plug-in hybrid electric vehicles (PHEVs) must have an electric range of at least 30km, and maximum tailpipe CO2 emission of 50 g/km. The definition excludes mild hybrid vehicles and full hybrid vehicles.

Mobility is a key factor for a fast-developing nation such as Malaysia. As the world changes, Malaysia must keep in step with how mobility is developing on a global scale. Electric Mobility is an effective means of ensuring environmental sustainability through reducing CO2 emissions, improving air quality and reducing the demand for fossil fuels [2]. With growing global concerns about climate change and the depletion of fossil fuels, the global transport sector is undergoing an electric evolution, creating a dynamic new industry for EVs and supporting systems [37].

Electric Mobility can have a very positive impact in Malaysia, both environmentally and economically. A widespread use of EVs, with zero CO2 tailpipe emissions, will significantly improve the environment and reduce the nation's carbon footprint [3]. Electric Mobility can enhance the efficiency and sustainability of public transportation systems and be introduced to improve access for marginalised groups such as the elderly and lower-income earners. In the long-term, Electric Mobility will save on fuel and maintenance cost for users, the Government, and the public at large. The introduction of Electric Mobility into public transport and the private automotive sector can be seen as leading the way to greater and more sustainable mobility for all Malaysians [4]. The transformation of Malaysia into a global Electric Mobility marketplace will also help to drive Malaysia's economic development, creating new industries and new jobs, if it becomes a leading player in this important growth sector.

In this project, an analysis and evaluation of current and prospective development of the EV sector will be provided, supporting ecosystem in Malaysia with proposed solutions to complement various governmental initiatives including the National Green Technology Policy, the Economic Transformation Programme (ETP), and the National Automotive Policy 2014 (NAP14).

Electric Mobility represents a disruptive, or game-changing, technology that provides a means to mitigate the impact of this sector while presenting opportunities for industry transformation and growth. However, the graphic below shows a Business as Usual

(BAU) scenario in which CO2 emissions from Malaysia's road transportation sector increases by 213% from 61.6 MtCO2eq in 2013 to 127 MtCO2eq in year 2030 [5], assuming that between year 2015 to 2030, no measures (existing or planned policy, programmes or other initiatives). This is due to Malaysia's urban population will rise to 82 percent of its total population expected 32.4 million in 2020, causing the rise of registered vehicles in Malaysia.

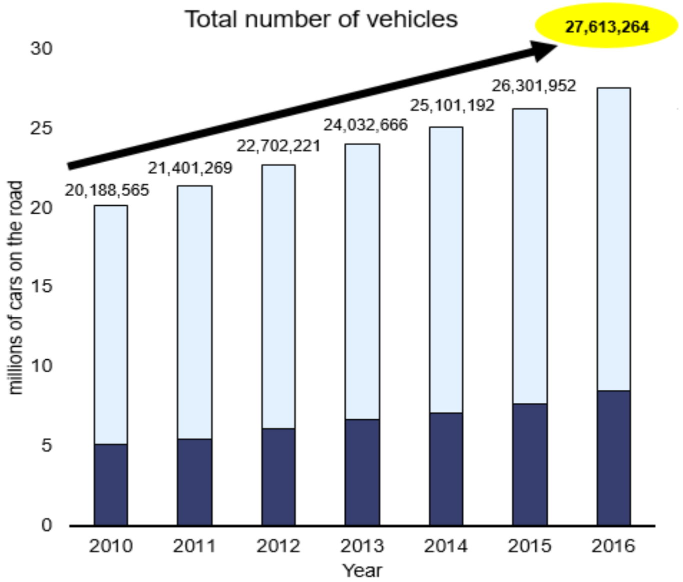

Figure 1: Total Registered Motor Vehicles in Malaysia

As demand for EVs grows steadily, a robust and sustainable integrated EV Ecosystem needs to be in place to support this growth. With this in mind, the second step to developing the EV market would be to plan for the necessary complex infrastructure for the large-scale adoption of Electric Mobility solutions. An EV Ecosystem is defined as a total environment to support mass operation of electric vehicles [1]. This encompasses "hard infrastructure" such as recharging technologies, smart grids and transport systems along with "soft infrastructure" such as regulation, business models, skills and community engagement.

This project aims to provide a comprehensive analytical electricity demand for electric vehicles (EV) and a strategic plan for the development of an electric vehicle (EV) sector and supporting ecosystem in Malaysia.

This project also identifies key challenges for the development of the EV sector in Malaysia, with strategies to meet these challenges, and opportunities that can arise out of them by reviewing Malaysia's current landscape for EV transportation, and existing and planned policies and initiatives encouraging the adoption of EVs.

Furthermore, this project discusses the argument for incentives and regulatory support and proposes actions to help lead Malaysia to its ultimate goal of becoming a global Electric Mobility marketplace – a model of Electric Mobility for the region, leading growth in EV use and infrastructure development; and a dynamic international marketplace for EVs, EV components and EV infrastructure.

Thus, the significance of this paper is to add value to the current knowledge of EV demand in Malaysia and it is hoped that the suggestions and recommendations at the end of this paper will spur the growth of EV in Malaysia in a sustainable manner.

OBJECTIVES

1. To determine the electricity demand in relation to electric vehicles by 2040.
2. To identify the challenges, strategies and opportunities of the growth of electric vehicles in Malaysia.
3. To propose a strategy / implementation plan of Electric Vehicles (EV).

METHODOLOGY

The paper starts with a few case studies to extract lessons to be learned from developed countries. In order to relate to positive implementation of EV programs and demands, a few countries are selected as comparisons. A summary of global outlook for EV adoption will also be presented. A comparison with Malaysian scenarios will be drawn upon which current strategies will be outlined. A projection of EV and electricity demand will be estimated using some statistical tools to enable outlook of the correlation between the two items to be calculated. Simplified calculations between costs and impacts of internal combustion engine (ICE) and EV will be presented to show benefits of EV ownership. The correlation between the potential EV rise and electricity demand will be presented in detail. Some challenges will be discussed in brief. Finally, suggestions for future adoption will be enlisted as far as Malaysia is concerned.

INTERNATIONAL CASE STUDY #1: AMSTERDAM, THE NETHERLANDS

Amsterdam has a population of over 780,000 people and approximately 250,000 registered vehicles. As part of its 'Clean Air for Amsterdam' action plan, the city aims to achieve 100 per cent EV usage by 2040 [6]. These will be powered by clean sources of energy generated by windmills, solar panels and biomass plants.

As at 2013, there were about 800 EVs on the road with over 600 charging stations – these numbers are expected to increase to 6,000 EVs and a network of 2,000 charging stations in 2015 [7]. In support of this aim, in 2009, the city launched a €3 million (RM12.3 million) *(All Euro conversions are based on €1: RM4.10 (February 25, 2015)* subsidy scheme to support companies intending to purchase electric vehicles including cars, taxis and trucks as a key means of transportation around the city, positioning Amsterdam as a green transportation hub. With the introduction of the scheme, Amsterdam recorded over 200 EVs purchased in 2009, clearly underlining the effectiveness of subsidies [8].

Figure 2: EV subsidies for Amsterdam

Additionally, EV users are eligible to file for tax reduction according to the total amount of greenhouse gases saved (GHG) [9]. The 'Car2Go' programme was launched in November 2011, providing 300 smart-for-two EVs as a mode of public transportation. The vehicles can be picked up and dropped off at any public parking spot inside the city's business area without limit on duration and location. The vehicles have a range of 135km and can be charged by the minute at €0.29 (RM1.19) or by the hour at €12.90 (RM52.89) [10].

The introduction of the subsidy scheme saw the first ten electric taxis on the roads of Amsterdam in May 2011. It also led to the birth of one of the world's first electric taxi operators, Taxi Electric, with a fleet of 25 vehicles [10]. As the average diesel taxi contributes nearly 35 times more to the nitrogen dioxide concentration in the city than an average petrol vehicle, the move to convert these diesel-powered vehicles to EVs is a fundamental move towards improving the city's air quality. Currently, Amsterdam has approximately 2,500 taxis on the roads and, with the commitment of taxi operators, the city hopes to deploy 450 electric taxis by 2015 [8]. As of March 2014, Taxi Electric's fleet had driven a total of 1.5 million kilometres without any interruption or breakdown, a testament to the resilience and reliability of electric cars.

As expected, car manufacturers were reluctant to invest in charging stations around the city without a guaranteed return. The Netherlands Government took the lead by building charging infrastructure to demonstrate its commitment to Electric Mobility and to encourage the private sector to follow suit. As of 2013, Amsterdam had around 600 charging stations citywide.

Amsterdam was also the first in the world to provide a real-time open Application Programming Interface (API) for charging infrastructure, focused on locations and availability. This has opened up possibilities for entrepreneurs to create mobile apps, in-car navigation systems and websites for EV users to locate the nearest available charging point [8].

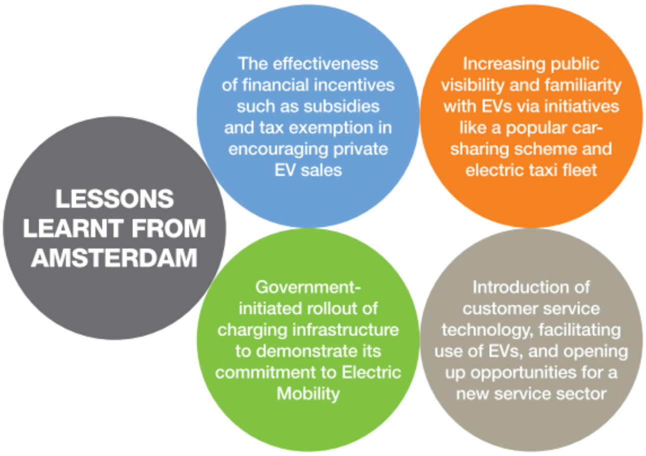

Figure 3: Lessons learnt from Amsterdam

INTERNATIONAL CASE STUDY #2: LOS ANGELES, USA

Los Angeles has a population of over 4.1 million and about 2.5 million registered vehicles. The ‘car capital of the world’ began deploying EVs as early as the 1990s and is committed to transforming Los Angeles into a plug-in electric car capital of the world. The city’s land transportation accounted for 43 per cent of the city’s total GHG emissions, including CO2, in 2012 [11].

The city is banking on EV technology to help reduce GHG emissions from transportation while also improving air quality and driving local and national economic growth. Los Angeles has become an attractive hub for electric vehicle manufacturers, currently being the headquarters for BYD [12] and CODA [13], as well as other companies within the global EV economy [2].

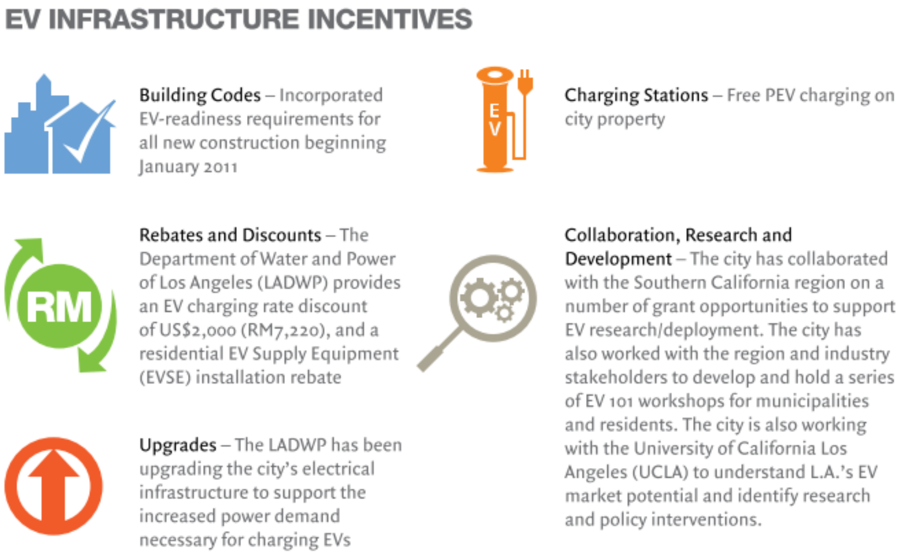

Figure 4: EV Infrastructure Incentives for L.A.

To encourage greater adoption of EVs, the federal government also offers L.A. consumers who purchase a new qualified plug-in electric motor vehicle a federal tax credit of up to US$7,500 (RM27,075). Consumers who purchased and installed qualified EV chargers were also eligible to receive a tax credit of up to US$1,000 (RM3,610) [1].

To further support the growth of EVs, in 2013, the LADWP launched a US$2 million (RM7.22 million) rebate programme, ‘Charge Up L.A.!’, aimed primarily at expanding EV charging networks to cater to rising demand [14]. The rebate programme, available from August 1, 2013 until June 30, 2015 or until funds are exhausted, whichever comes first, is offered on a first-come, first-served basis to the first 2,000 approved EV customers regardless of customer sector.

Figure 5: Lessons learnt from L.A.

GLOBAL OUTLOOK: CURRENT NATIONAL POLICY PROGRAMS

National policy programs as implemented by leading EV markets are summarized as follows [17]:

Table 1: Selected national policy programs

EVI Members	Financial	Infrastructure	RD&D
China [18]	Purchase subsidies for vehicles of up to RMB60,000	Various types from charging stations to manufacturing facilities	RMB6.95 billion for demonstration projects
Denmark [19]	Exemption from registration and road taxes	kr.70 million for development of charging infrastructure	Focus on integration EVs into the smart grid
Finland [20]	€5 million reserved for vehicles participating in national EV development programme, ending in 2013	€5 million reserved for vehicles participating in national EV development programme, ending in 2013	-
France [21]	€450 million rebates given to consumers buying efficient vehicles, with 90% of that amount from fees on inefficient vehicles. Remaining 10% (€45M) is a direct subsidy	€50 million to cover 50% of EVSE cost (equipment and installation)	€140 million budget with focus on vehicle RD&D
Germany [22]	Exemption from road taxes	Four regions nominated as showcase regions for BEVs and PHEVs	Financial support granted for R&D for electric drivetrains, creation and optimisation of value chain, information and communications technology (ICT) and battery research
India [23]	INR100,000 or 20% of cost of vehicle, whichever is less. Reduced excise duties on BEV/ PHEVs	The National Missions for Electric Mobility will facilitate installation of charging infrastructure	Building R&D capability through joint efforts across government, industry and academia. Focus on battery cells and management systems
Italy [24]	€1-5 Million for consumer incentives, ending in 2014	-	-
Japan [25]	Support to pay ½ of the price gap between EV and corresponding ICE vehicles, up to ¥1 million per vehicle	Support to pay for ½ of the price of EVSE (up to ¥1.5 million per charger)	Major focus on infrastructure RD&D
Netherlands [8]	Tax reduction on vehicles amounting to 10-12% net of the investment	400 charging points supported through incentives	Focus on battery RD&D (30% of 2012 spending)
Norway [15,16]	200,000 EVs at zero tax	Highest number of EV percapita	Encourage and support fleet and municipal transport
Spain [26]	Incentives up to 25% of vehicle purchase price before taxes, up to €6,000. Additional incentives of up to €2,000 per EV/PHEV also possible	Public incentives for a pilot demonstration project. Incentives for charging infrastructure in collaboration between the national government and regional administrations	Five major RD&D programmes are operational with incentives for specific projects
Sweden [27]	€4,500 for vehicles with emissions of less than 50 grams of CO_2/km. €20 million for 2012- 2014 supercar rebate	No general support for charging points besides RD&D funding (€1 million in 2012)	€2.5 million for battery RD&D
United Kingdom [28]	-	£37 million for thousands of charging points for residential, street, railway and public sector locations. Available until 2015	The UK Technology Strategy Board has identified 60 collaborative R&D projects for low-carbon vehicles
United States [29]	Up to $7,500 tax credit for vehicles based on battery capacity. Phased out after 200,000 vehicles from qualified manufacturers	A tax credit of 30% of the cost, not to exceed $30,000 for commercial EVSE installation; a tax credit of up to US$ 1,000 for consumers who purchase qualified residential EVSE. $360 million for infrastructure demonstration projects	2012 budget of $268 million for battery, fuel cell, vehicle systems and infrastructure R&D

OPERATING RESERVE

To balance the energy demand for EVs, a secure, steady, and sustainable electricity supply must also be in place. In many countries, this depends very much on the operating and spinning reserve of the electricity supply systems. Operating reserve is the generation capacity that is available to the system operator within a short interval of time to meet demand in case a generator experiences an unexpected outage or there is another disruption in supply [30]. The operating reserve is made up of both spinning reserve and non-spinning reserve.

Table 2: Operating reserve definitions

Operating Reserve Type	**Explanation**
Spinning Reserve	Spinning reserve is any back-up energy production capacity that can be made available to a transmission system with a 10minutes notice and can operate continuously for at least two hours once it is brought online.
Non-Spinning Reserve	Non-spinning reserve is generation capacity which is capable of being brought online within 10 minutes if it is offline, (or interrupted within 10 minutes if it is online), and which is capable of either being operated or interrupted for at least two hours.

Table 3: Operating reserve requirement

Year	Spinning Reserve		Largest coal unit	Largest CCGT block	Target operating reserve
	Loss of largest unit in the system	Regulating reserve			
2015	1000MW	200MW	700MW	700MW	2,600MW
2016-2019	1000MW	200MW	1000MW	700MW	2,900MW

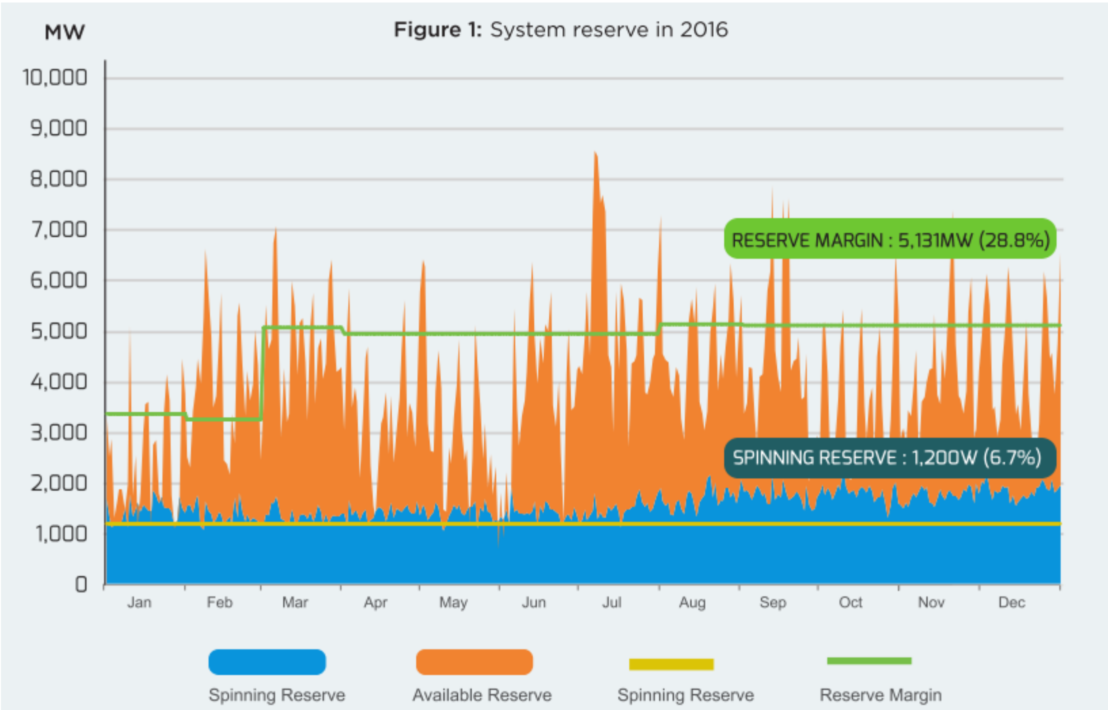

Figure 6: System reserve in 2016

RESERVE MARGIN

The main reason for the prevalent use of reserve margin as a reliability criterion is its ease of calculation and understanding. Reserve margin is a deterministic measure and represents the relative amount of the installed generating resources being greater than the annual peak loads. If the calculated reserve margin is above the criterion, then the system would be within the criteria for the period evaluated. The percentage of reserve margin criteria must be at a minimum of 20% which relates to the provision of sufficient generation capacity to meet the demand [30]

RENEWABLE ENERGY FOR EV

Solar panels for charging

The amount of electricity a solar panel produces depends on three main things: the size of the panel, the efficiency of the solar cells inside, and the amount of sunlight the panel gets. Solar efficiency relates to the amount of available energy from the sun that gets converted into electricity. Back in the 1950s, the first solar cells were capable of taking 6% of the energy from the sun and converting it into electricity, about a third of energy to light up a 60-watt incandescent bulb. In 2012, solar cells could convert 15% of the energy hitting them from the sun into power. As of 2017, solar cell efficiency is closer to 20%.

The typical solar energy system includes solar panels, an inverter, equipment to mount the panels on the roof, and a performance monitoring system that tracks electricity production. The solar panels collect energy from the sun and turn it into electricity, which is passed through the inverter and converted into a form that can be used to power the house.

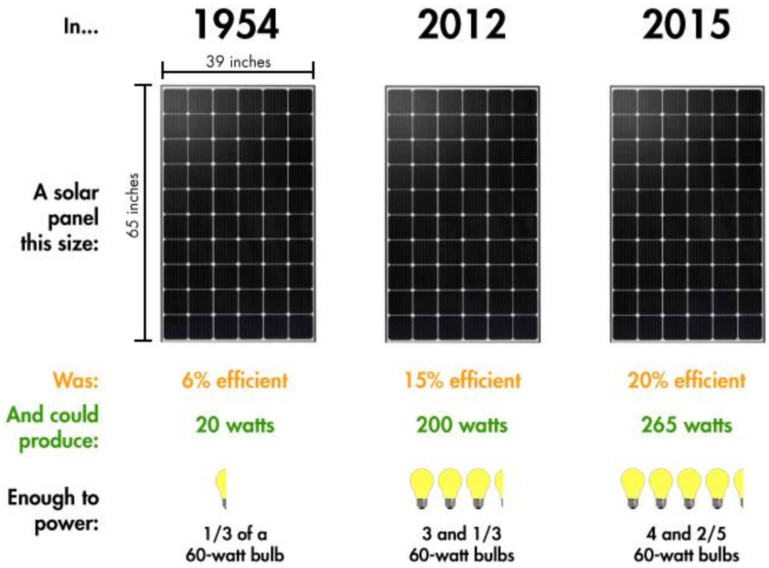

Figure 7: History of solar panels

Most residential solar energy systems are connected to the electricity grid (or "grid-tied"). When solar panels are producing more electricity than the home needs, the excess is fed back into the power grid. Conversely, when the house needs more electricity than the solar panels are producing, power can be drawn from the electric grid.

In most cases, a credit can be received in the utility bill for the electricity that has been sent back to the grid. When more electricity is used than the solar panels have generated, more have to be paid to the utility. This process is known as net energy metering.

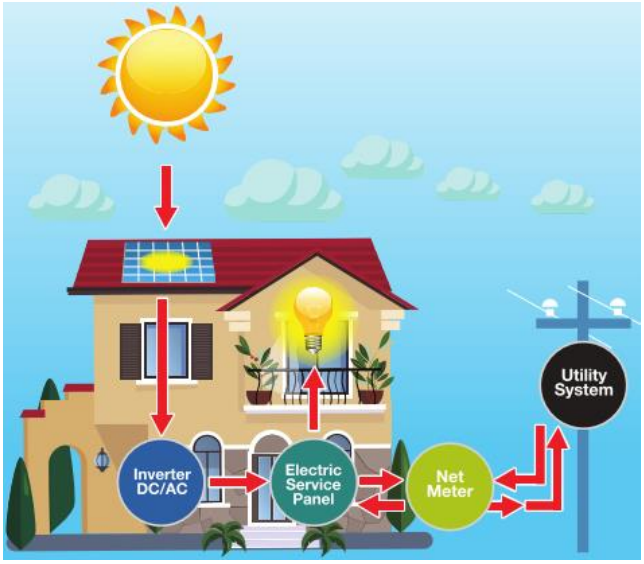

Figure 8: NEM interconnection to utility system

Net energy metering

Suruhanjaya Tenaga has been entrusted by the Government to increase the capacity of solar PV installations in the power sector by introducing net energy metering arrangement to facilitate consumers to install solar PV systems for self-consumption and supply any excess energy to the electricity supply utilities [31].

On 6th October 2016, the Minister of Energy, Green Technology and Water launched the NEM scheme which will complement the current FiT mechanism. This scheme is to encourage the deployment of RE as meted out in the Eleventh Malaysia Plan (RMK-11) [32].

The Net Energy Metering (NEM) applicant shall be a registered consumer of the Distribution Licensee (DL) in the Peninsula, Sabah and Labuan. Connection type of NEM scheme to the Distribution Licensee Network shall be done only through indirect connection. Prior to the approval of NEM application, the applicant shall perform NEM Assessment Study to determine the technical feasibility of connecting proposed installation to the Distribution Licensee's electricity distribution network. The findings of the study will assist the NEM applicant to decide on the feasibility of the project in terms of cost and assist the Distribution Licensee to prepare the technical requirements needed for interconnection [32].

Electric vehicle supply equipment (EVSE) – charging infrastructure

The charging infrastructure requirements include the number of stations and plugs required to provide a convenient and ubiquitous network of PEV charging opportunities that will evolve as EV adoption increases.

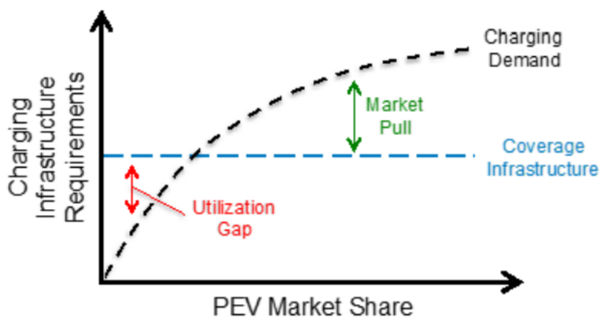

Figure 9: PEV charging requirements evolution as a function of PEV market share

Figure 9 illustrates coverage (blue line) and demand (black line) infrastructure requirements for different PEV market shares. The coverage requirement is independent of PEV adoption: even if few PEVs are deployed, a ubiquitous network of stations is required to enable long-distance travel, prevent range anxiety, and promote PEV adoption. Therefore, a "utilization gap" exists at low PEV market shares, which is characterized by a market demand for charging infrastructure that is lower than the required coverage infrastructure; the infrastructure is underutilized, which negatively impacts station financial performance and makes it difficult to justify investment in new stations. As PEV adoption increases, the demand for charging infrastructure exceeds the coverage infrastructure, creating "market pull" for the installation of additional charging stations or the addition of plugs to existing stations [33].

Charging availability

Charging availability at a point in time is the percentage of EVSE in a geographical area that are connected to a vehicle [29]. The charging availability curve for residential EVSE is a periodic curve with both daily and weekly patterns. The daily peaks and troughs of the curve correspond to the night time and day time, respectively. The peaks are caused as people return to their residences and plug in their vehicles in the evening. The troughs are caused as people unplug their vehicles and (presumably) leave their residences. The weekly pattern revolves around the weekends. The weekend days tend to have lower peaks and higher troughs than the weekdays. Higher troughs during the day result from fewer people unplugging their vehicles on weekend days. Lower peaks are due to the fact that fewer EVSE, which had been disconnected, were connected in the evening.

The daily and weekly patterns in the charging availability curve can be displayed using a 24-hour time-of-day plot for weekdays and another 24-hour time-of-day plot for weekend days. This kind of time-of-day plot is a concise way to visualize the daily behaviour of many calendar days of data simultaneously.

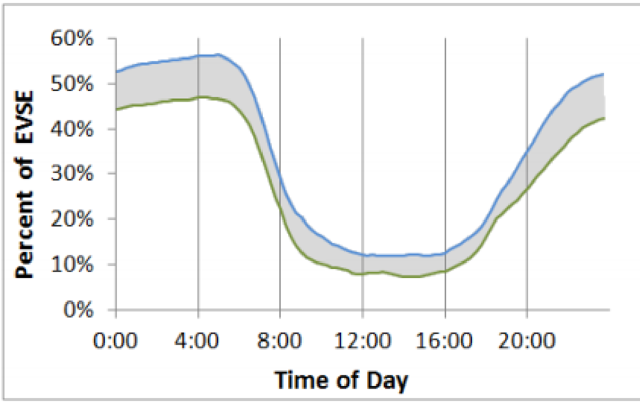

Figure 10: Weekday time-of-day charging

Charging demand

Charging demand at a point in time is the total amount of power being drawn from the electric grid by a group of EVSE in a geographical area. This is typically shown as a curve of charging demand versus time, which is sometimes referred to as a load profile.

The charging demand curve is a periodic curve, with both daily and weekly patterns similar to the charging availability curve. The daily peaks and troughs of the charging demand curve correspond to the night time and day time, respectively. The demand at night is high, whereas the demand during the day is close to zero. This indicates a strong preference among EV Project participants for night-time residential charging. The weekly pattern revolves around the weekends. The lowest demand occurs on the weekend days. Demand increases on each weekday until it reaches a peak on Wednesday or Thursday night. Then demand diminishes again as the weekend comes.

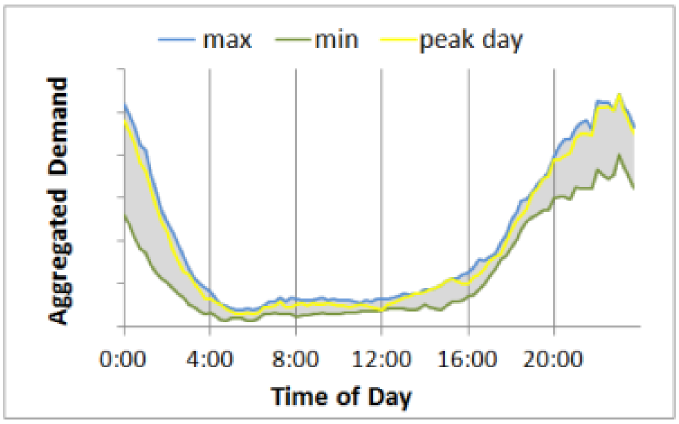

Figure 11: Time-of-day demand plot with peak day

Electricity demand forecast

Key factors contributing towards electricity trend includes structural changes in the economy. Increase in electricity tariff has also contributed to the declining sales as consumers changed their consumption behaviour and adopted to energy efficiency (EE) measures. Amount of energy generated by RE sources has increased especially through self-generation, be it for own consumption or feed-in to the grid system [30].

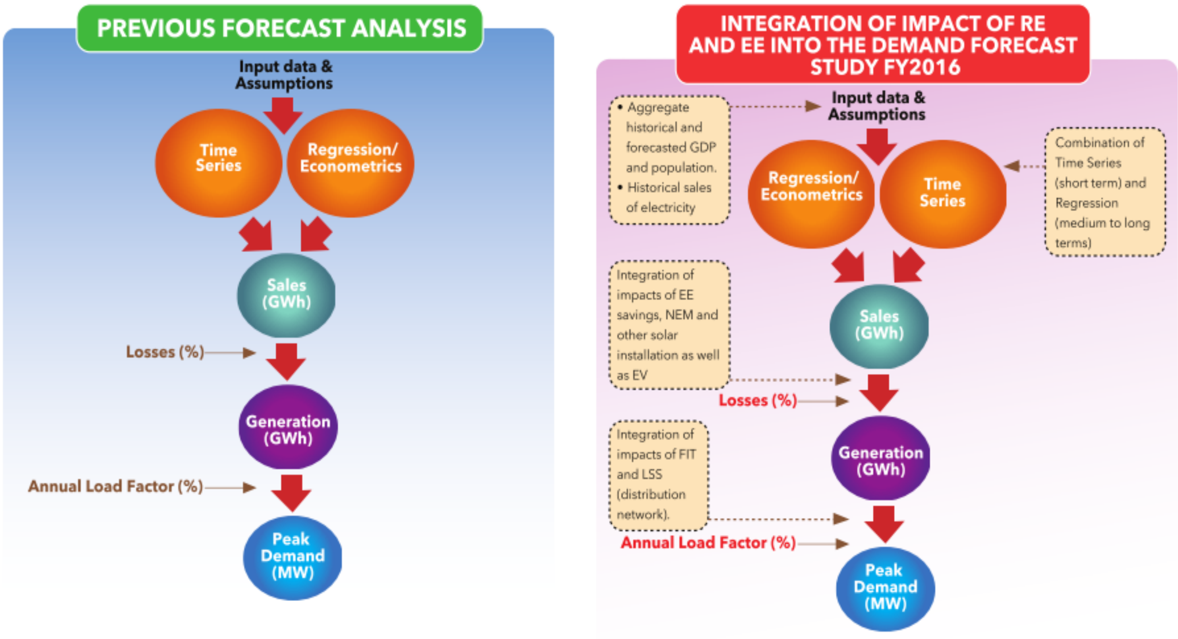

Figure 12: Demand forecast study methodology

CO2 emission reduction

Analysis that was undertaken shows that the comprehensive adoption of Electric Mobility strategy could help to reduce Malaysia's CO2 contribution from the transportation sector by up to 0.6 MtCO2eq by 2020. Based on the analysis, the CO2 reduction by 2020 will be as follows:

Table 4: CO2 emission reduction for cars

Cars	2015	2016	2017	2018	2019	2020
Cumulative Target (Unit)	200	550	2100	15100	40100	100000
Cumulative CO2 emissions Reduction for EVs (tCO2)	640	1760	6721	48300	128345	320063

Table 5: CO2 emission reduction for buses

Buses	2015	2016	2017	2018	2019	2020
Cumulative Target (Unit)	57	130	313	660	1200	2000
Cumulative CO2 emissions Reduction for EVs (tCO2)	5080	11586	27895	58821	106947	178245

Table 6: CO2 emission reduction for scooters & motorcycles

Scooters & Motorcycles	2015	2016	2017	2018	2019	2020
Cumulative Target (Unit)	2100	6000	15000	30000	55000	100000
Cumulative CO2 emissions Reduction for EVs (tCO2)	1729	4939	12347	24694	45273	82314

Table 7: Total potential CO2 emission reduction by 2020 (tCO2)

	Electric cars	Electric buses	Electric Scooters & Motorcycles
Potential CO2 Emissions Reduction by 2020 (tCO2)	2100	6000	15000
Total Potential CO2 Emissions Reduction by 2020 (tCO2)	1729	4939	12347

CORRELATION BETWEEN KEY FACTORS OF EV

Correlation between population and CO2 emission

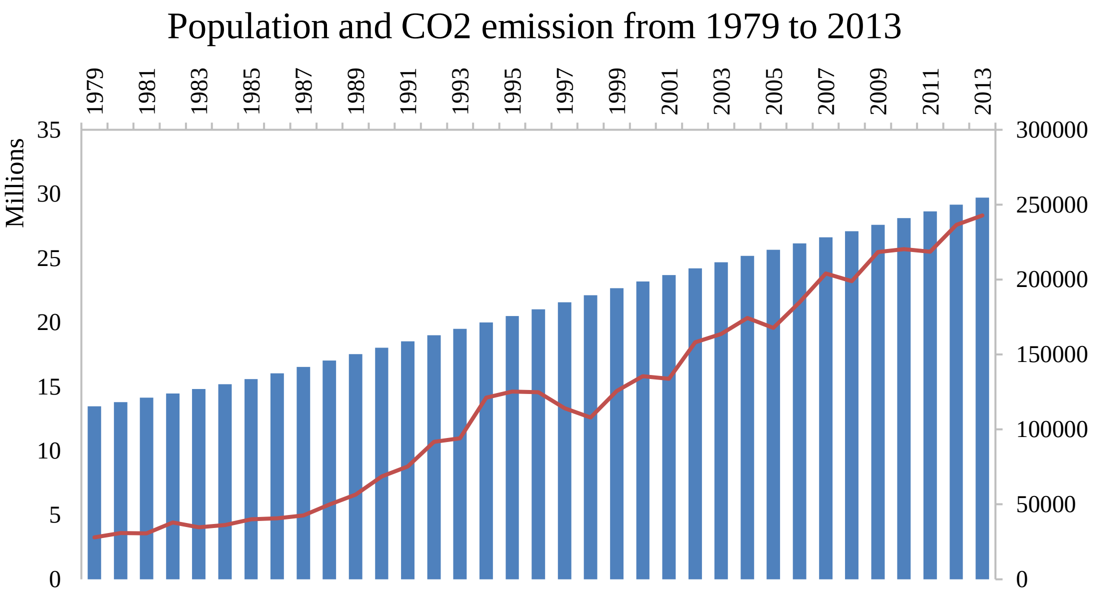

Figure 13: Population and CO2 emission from 1979 to 2013

Correlation = 0.9884 (Significant)
P-value = 3.07099E-32 (Highly significant)
From Figure 13, the correlation between population and CO2 emission from 1979 till 2013 is significant at a value of 0.9884. It indicates that CO2 emission increases with the increase of population. The Malaysian population is growing fast at a rate of 1.94% per annum averagely. Due to the increasing number of vehicles, the CO2 emission has also increased by 88.4% from 27,998 kilo tonnes to 242,821 kilo tonnes.

Correlation between number of active cars and total rail lines route

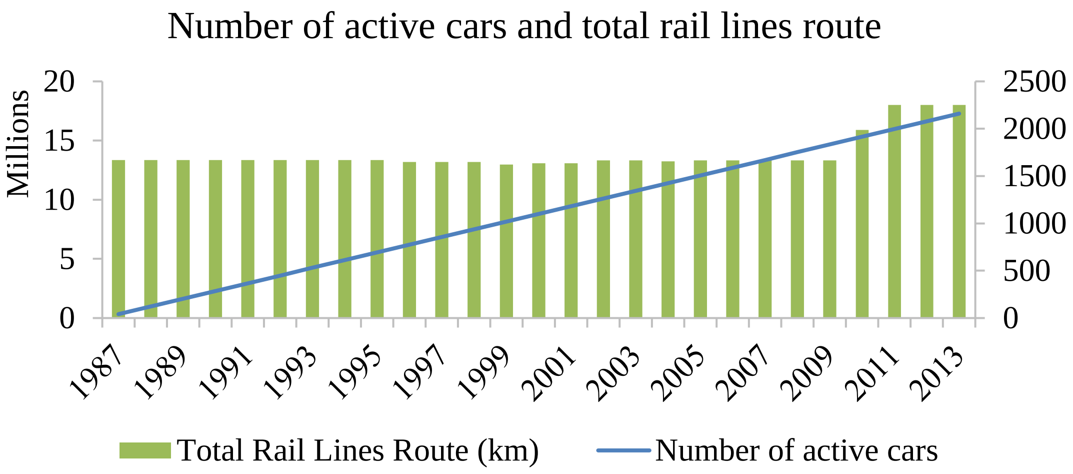

Figure 14: Number of active cars and total rail lines route

Correlation = 0.5999 (Insignificant)
P-value = 0.0009 (Medium)
From Figure 14, the correlation between number of active cars and total rail lines route is insignificant. Malaysian still chooses to travel with their own private ownership vehicles despite of the increasing number of total rail lines route. Therefore, it can be predicted that the number of active vehicles will continue to increase due to the increasing number of population.

NUMBER OF ELECTRIC VEHICLES FORECAST

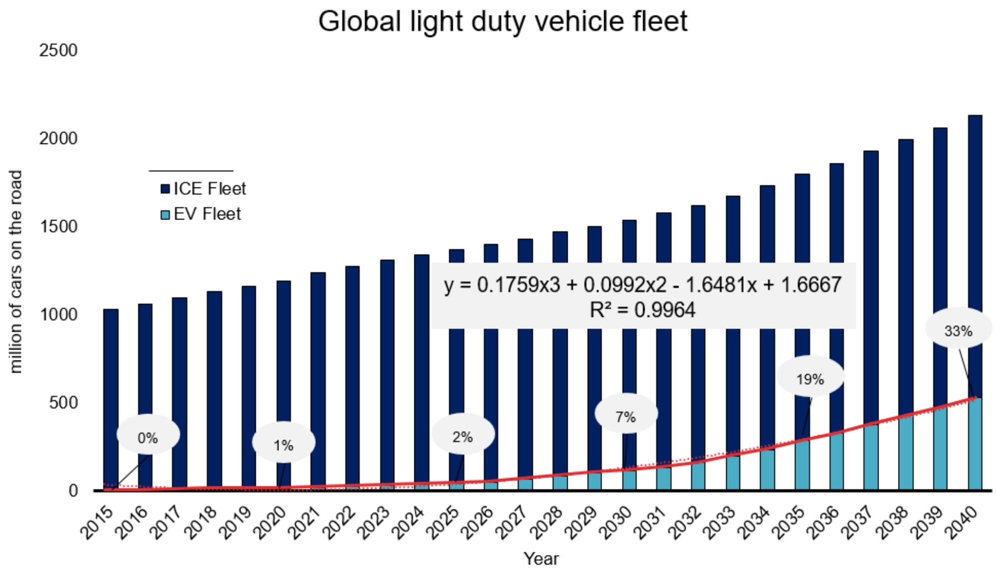

Figure 15: Number of electric vehicles forecast

From Figure 15, 11 million of EV is expected on the road by 2040 (33% of total number of vehicles in Malaysia) in BAU scenario. This projection augurs well with the forecast by IEA [37].

ELECTRICITY DEMAND FORECAST

Malaysia has continuously brought in various models of battery electric vehicles (BEV) and plug-in hybrid electric hybrid (PHEV) to the market in the recent years.

Table 8: Typical models for PHEV and BEV in Malaysia

Types	Brand / Model		Price (RM)	Horsepower (hp)	Torque (Nm)	Battery type	kWh	km	g/km CO2	km/kWh	kWh/km
PHEV	BMW	i8	1,188,800	96	250	Li-ion	7	37	49	5.285714	0.189189
		330e Sport	258,800	87	250	Li-ion	5.7	37	49	6.491228	0.154054
		740Le	598,880	113	250	Li-ion	9.2	41	56	4.456522	0.224390
		i3	399,000	170	270	Li-ion	33	300	N/A	9.090909	0.110000
		XS 40e M-S3	388,800	113	250	Li-ion	9.2	31	77	3.369565	0.296774
	Mercedes Benz	C350e AMG-Lihe	299,888	80	340	Li-ion	6.2	31	48	5.000000	0.200000
		E350e AMG-Lihe	396,888	87	440	Li-ion	6.2	33	57	5.322581	0.187879
	Volvo	S90 T8+	368,888	87	240	Li-ion	10.4	50	46	4.807692	0.208000
		XC90T8	403,888	87	240	Li-ion	9.2	40	49	4.347826	0.230000
BEV	Nissan	Leaf	180,566	109	254	Li-ion	24	195	N/A	8.125	0.123077
		Zoe	145,888	87	220	Li-ion	22	210	N/A	9.545455	0.104762
		Twizy	71,888	17	57	Li-ion	6.1	100	N/A	16.39344	0.061000
		Leaf (2017)	123,222	148	320	Li-ion	40	378	N/A	9.45	0.105820
										Average kWh/km	0.168842

Sample calculation:

Energy consumption of EV = 0.168842 kWh/km
Vehicle kilometer travel for cars = 21,216 km/year
Electricity demand per car per year = Energy consumption of EV × Vehicle kilometer travel for cars
Electricity demand per car per year = 3582.152 kWh

Electricity consumption from EVs will rise to 41GWh by 2040. The overall trend of the electricity demand due to growth of EVs in Malaysia is increasing exponentially by growing 54.11% growth annually. By 2040, the total number of active EVs will record at the highest of 11,626,146. Assuming each of the EVs consume about 3582.19kWh power of electricity averagely, the electricity demand for EVs will be 41,646,623,185Wh.

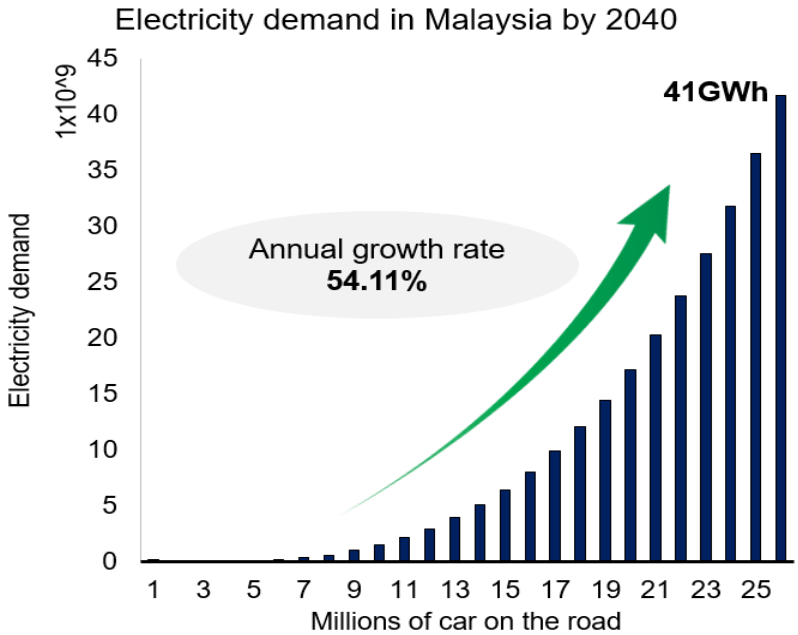

Figure 16: BAU scenario to the electricity demand by EV in 2040

The 'peakness' of fast-charging load profiles will need to be managed by utilities and regulators through the introduction of time-of-use rates to encourage off-peak charging, as well as storage solutions at the operator site which can mitigate high power demand from the grid. Fossil fuel demand will be displaced by the growing fleet of EVs.

EV CHARGING INFRASTRUCTURE

EV owners are normally supplied with home or private charging equipment when purchasing their vehicles. These systems are compatible with household electricity outlets and provide slow/overnight-charging. However, accessible public-access charging facilities are critical to increase consumer confidence and support an EV lifestyle.

Public-access charging infrastructure includes charging stations owned by retailers, EVSE companies, commercial interests, as well as those installed by governments and municipalities. It can also include residential and workplace charging infrastructure which can be shared.

One huge advantage of EVs is the potential to charge their batteries at convenient locations. Future EVSE installations need to be market-driven, focusing on areas such as workplaces and shopping malls. Public / private partnerships between municipalities, utilities, building owners/corporate companies and infrastructure providers are important.

There are two types of charging infrastructure for EVs: slow chargers and fast chargers. Slow chargers are the most common type of charging infrastructure, providing alternating current to the vehicle's battery from an external charger. Charging times can range from 4 to 12 hours for a full charge. Fast charging (also known as "DC quick charging") stations provide a direct current of electricity to the vehicle's battery from an external charger. Charging times can range from 0.5 to 2 hours for a full charge [17].
Most existing Malaysian public-access charging stations deploy slow chargers, in accordance with harmonised charging standards to ensure that all currently available EV models can fully utilise them. Presently, there are only two fast chargers available to the public.

A national technical committee oversees the adoption and harmonisation of EV standards and will address strategies and solutions with automotive manufacturers and charging infrastructure providers as required.

Malaysia's rollout of public-access charging infrastructure is currently focused on slow chargers. However, once the use of electric cars becomes more commonplace, the diversification of charger types will increasingly become necessary to provide options for

EV drivers. Fast chargers, which can fully charge a car within 60 minutes, will need to be installed in areas with a greater concentration of electric vehicles.

There are 3 types of chargers that are currently deployed in Malaysia. [35]

Table 9: Types of Chargers available in Malaysia

Charger type	3.7kW AC Charger	7kW AC Charger	22kW Fast Charger
Power requirement	Single Phase 16A, 240V	Single Phase 32A, 240V	Three Phase 32A, 415V
Connection requirement	Single Phase connection preferably at main switch board (MSB). Otherwise, at sub-distribution box direct from sub-switch board (no more than 3rd tier)		Three Phase connection at MSB
	Good ground (earth) resistance Value to be < 150 Ohm in all cases		
Charging time	4 to 6 hours	3 to 4 hours	1 hour
Operating cost (per day)*	RM 4.80	RM 9.00	RM 28.40

*Operation cost is calculated based on an electricity tariff of 43 cent/kWh with charging station utilisation of 3 hours a day.

IMPACT MODELLING

EVs could be in both commercial and private ownership car such as electric buses, electric car and scooter sharing. EVs play a fundamental role in Malaysia's EV Ecosystem, privately-owned EVs should in the longer term make up the majority of EVs in the transportation landscape, with private/corporate purchasing of EVs becoming a main driver of an evolving Malaysian EV Economy.

The economic benefits of EVs for the Malaysian consumer are significant, as demonstrated in the chart below.
Assumptions: (Based on car useful life 10 years)

1. *Annual mileage 21,216 km*
2. *Petrol car fuel consumption 6.3 litres/100km*
3. *Fuel price RM2.30 per liter*
4. *Fuel subsidy RM0.27 per litre*
5. *Petrol car maintenance cost RM0.11 per km*
6. *Stationary fuel consumption 1.2 litre/hour*
7. *CO2 emissions 152 g/km*
8. *Electric car battery pack 24 kWh*
9. *Maximum range 200 km*
10. *Electric car maintenance cost RM0.04 per km*
11. *Zero tailpipe emission, energy consumption 14.25kWh/100km*
12. *Electricity tariff average domestic RM0.3166 per kWh*
13. *Electricity subsidy RM0.09 per kWh*
14. *Battery second life value RM326 per kWh*
15. *Time in slow moving traffic 0.4hour/day*
16. *External Cost Savings EUR15/tCO2*

Table 10: Long-term benefits of EVs vs. ICEs

Based on 10 years useful life	Petrol car	Electric car	Difference	Savings	Beneficiary
Fuel/Electricity cost	RM 30,742	RM 9,572	RM 21,170	69%	Rakyat
Maintenance cost	RM 23,338	RM 8,486	RM 14,852	64%	
Stationary traffic fuel cost	RM 4,030	RM 0	RM 4,030	100%	
Battery second life value	n/a	RM 7,824	RM 7,824	100%	
Subsidy cost to Government (pre 1/12/2014)	RM 3,609	RM 2,721	RM 888	25%	Government
External cost savings	n/a	RM 2,044	RM 2,044	100%	
CO2 tailpipe emission	32,248 kg-CO2	0 kg-CO2	32,248 kg-CO2	100%	
Total benefits from Electric Mobility			RM 50,808		

Simplified calculation ICE vs EV costs

A. For Petrol Car:

1. Fuel cost = Annual mileage × Petrol car fuel consumption × Fuel price × 10 years useful life

$$Fuel\ cost = \frac{21{,}216km}{year} \times \frac{6.3\ litres}{100km} \times \frac{RM\ 2.30}{litre} \times 10\ years\ useful\ life$$
$$Fuel\ cost = RM\ 30{,}742$$

2. Maintenance cost = Annual mileage × Petrol car maintenance cost × 10 years useful life

$$Maintenance\ cost = \frac{21{,}216km}{year} \times \frac{RM\ 0.11}{km} \times 10\ years\ useful\ life$$
$$Maintenance\ cost = RM\ 23{,}338$$

3. Stationary traffic fuel cost = Stationary fuel consumption × Time in slow moving traffic × 365 days/year × 10 years useful life

$$Stationary\ traffic\ fuel\ cost = \frac{1.2\ litres}{hour} \times \frac{0.4\ hour}{day} \times \frac{365\ days}{year} \times 10\ years\ useful\ life$$
$$Stationary\ traffic\ fuel\ cost = RM\ 4{,}030$$

4. CO2 tailpipe emission = CO2 emission × Annual mileage / 1000g

$$CO2\ tailpipe\ emission = \frac{152\ g}{km} \times \frac{21{,}216\ km}{year} \times \frac{kg}{1000\ g} \times 10\ years\ useful\ life$$
$$CO2\ tailpipe\ emission = 32{,}248\ kg\ CO2$$

B. For Electric Car:

1. Electricity cost = Energy consumption × Annual Mileage × Electricity tariff average domestic × 10 years useful life

$$Electricity\ cost = \frac{14.25\ kWh}{100\ km} \times \frac{21{,}216\ km}{year} \times \frac{RM\ 0.3166}{kWh} \times 10\ years\ useful\ life$$
$$Electricity\ cost = RM\ 9{,}572$$

2. Maintenance cost = Annual mileage × Electric car maintenance cost × 10 years useful life

$$Maintenance\ cost = \frac{21{,}216\ km}{year} \times \frac{RM\ 0.04}{km} \times 10\ years\ useful\ life$$
$$Maintenance\ cost = RM\ 8{,}486$$

3. Battery second life value = Battery second life value × Electric car battery pack

$$Battery\ second\ life\ value = \frac{RM\ 326}{kWh} \times 24\ kWh$$
$$Battery\ second\ life\ value = RM\ 7{,}824$$

4. External cost savings = CO2 tailpipe emission for petrol car × External Cost Savings

$$External\ cost\ savings = 32.248\ tonne \times \frac{EUR\ 15}{tonne} \times \frac{RM\ 4.20}{EUR}$$
$$External\ cost\ savings = RM\ 2{,}044$$

5. Total benefits from Electric Mobility = Difference of fuel/electricity cost + Maintenance cost + Stationary traffic fuel cost + Battery second life value + Subsidy cost from Government + External saving costs

$$Total\ benefits\ from\ Electric\ Mobility = RM\ 21{,}170 + RM\ 14{,}852 + RM\ 4{,}030 + RM\ 7{,}824 + RM\ 888 + RM\ 2{,}044$$
$$Total\ benefits\ from\ Electric\ Mobility = RM\ 50{,}808$$

However, the present unfamiliarity with EV technology greatly contributes to the market hesitancy of consumers. As with any new product and technology, consumers may adopt a sceptical approach during the introduction period, more so when it may involve a high investment. They are likely to spend considerable time on research or refrain altogether from making purchasing decisions until the product achieves maturity and, typically, prices reduce. During this stage, education, targeted communications and direct exposure or experience are important to influence and educate consumers' perception and purchase behaviour.

It is anticipated that the initial step of deploying EVs in public transport will create much needed public awareness on the viability of EVs for transportation, and this will lead to better appreciation and acceptance of EVs overall. It will also catalyse the development of an EV Ecosystem, including charging infrastructure and customer service, ready to support growing numbers of privately-owned EVs.

TRANSPORT ELECTRICITY DEMAND IN TOTAL ENERGY DEMAND

According to the National Energy Balance 2018 [36], transport sector consumed the highest amount of energy at about 43.3% (about 22,357 ktoe) in 2013 compared to 37.0% (about 17,728 ktoe) in 1993. The increasing energy consumption has led to a staggering increase in carbon dioxide (CO_2) emissions, as much as 184.9% over the last 40 years. Malaysia is ranked third after Indonesia and Philippines in terms of CO_2 emission from the transport sector in ASEAN countries. In 2016, out of the total carbon emissions from the land transport sector, 71% originated from cars and 9% from motorcycles. Hence, fuel efficiency and carbon emission levels for individual vehicles will have a significant impact on the environment. In order to mitigate the transport sector's emission and to keep the sector environmentally friendly, the adoptions of a sustainable and green transportation system will have to be made a priority.

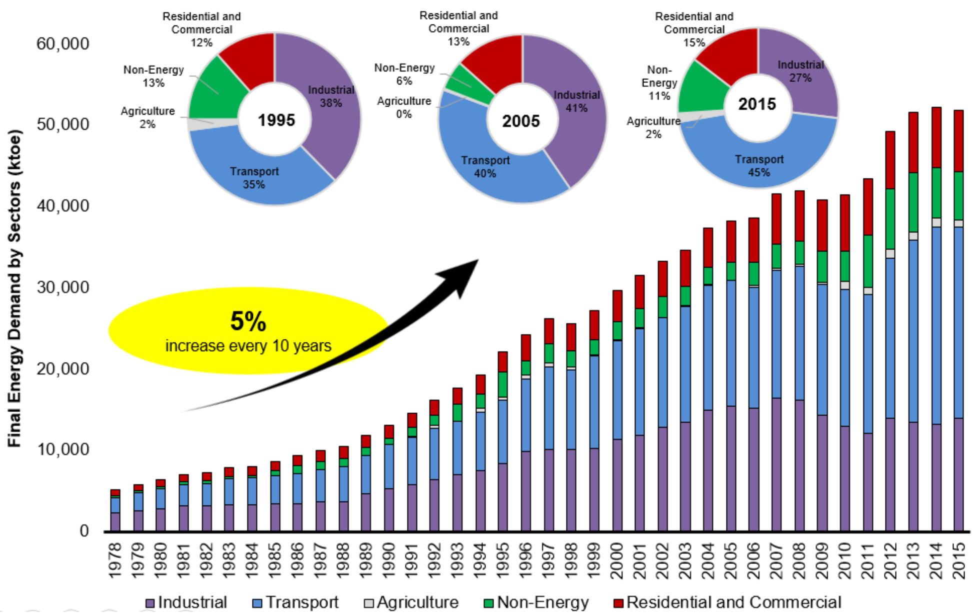

Figure 17: Final Energy Demand by Sectors (ktoe)

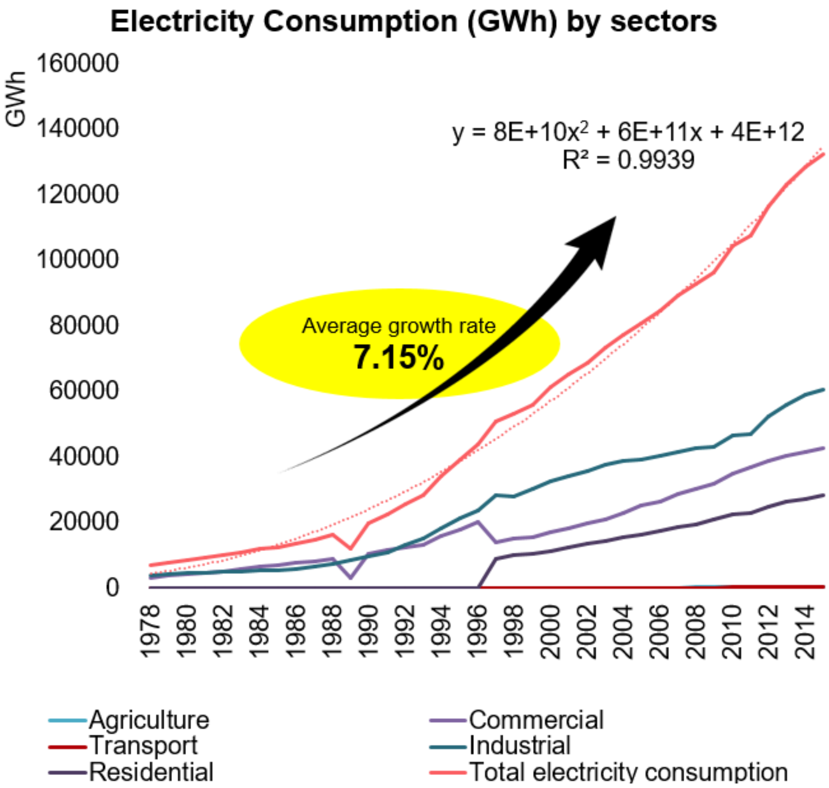

Figure 18: Electricity consumption (GWh) by sectors

The electricity consumption from the rail transport sector, increased moderately from 22.4 ktoe (260 GWh) to 22.9 ktoe (266 GWh) in 2015. By 2040, the electricity consumption for EV will be 41GWh in addition to the total electricity consumption in Malaysia.

FUTURE RECOMMENDATIONS

The impact of autonomous driving is imminent for the next 10 years, but ride hailing and car sharing services will have an impact sooner. Autonomous vehicles will be primarily shared and will begin to replace existing human-driven shared and hailed cars starting in 2030. This will start to impact vehicle sales and increase the average distance travelled per vehicle. It is expected that 80% of all autonomous vehicles in shared applications to be electric by 2040 due to lower operating costs.

The global outlook for Electric Mobility, and the EV market [37], is very positive indeed, with car sales doubling annually since 2011 to over 200,000 in 2013, and experts projecting 7.5 million electric cars on the road by 2020. The market for electric scooters and motorcycles is also growing exponentially, with researchers projecting that annual two-wheeled electric vehicle sales are set to increase 13 per cent during the next decade to 6 million, or a cumulative 55 million on the road by 2023.

With this young market currently being led by the United States, Europe and China, the time is ripe for Malaysia to position itself as a pioneer in Electric Mobility, and a nexus for expanding and driving its growth in the Southeast Asian region as a global Electric Mobility marketplace. There is much to learn from the example of nations and cities who are today leading the world in the electric evolution of the transportation landscape.

The considerable incentives and tailored programmes initiated by Governments and city policy-makers around the world to support the deployment of EV ecosystems appear focused on attaining immediate benefits derived from environmental enhancement, as well as broader economic benefits in the longer term.

However, as seen both in the case studies and the wider overview of national policy incentives and broad sampling of Electric Mobility initiatives worldwide, different markets/communities range a great deal in the ambitiousness of their targets, types and level of financial incentives, scale of expenditure on infrastructure and R&D, and scope of their Electric Mobility initiatives.
When looking to the examples cited above, it is important to consider what measures might be most effective in and suitable to the Malaysian context. In summary, these are some of the key steps in jump-starting the EV market that should be taken into consideration in Malaysia:

- Providing financial incentives – tax rebates and subsidies are a common means of encouraging private EV purchases. With Malaysia's high rate of import tax on vehicles, a financial incentive of 100% import tax exemption on EVs would provide a sweeping and attractive incentive for vehicle purchasers to choose EVs. The responses by the government through the recent 12th Malaysia Plan and budget 2022 are most laudable.

- Bringing EVs into public transportation, through electric buses, car-sharing programmes and electric taxi trials.
- Encouraging and supporting municipal and corporate fleets.
- Initiating electric scooter sharing programmes – this would be highly effective in the Malaysian transportation landscape, where motorcycles account for 46.6% of vehicles on the road.
- Instituting other regulatory measures or incentives, such as a requirement or advantage for property developers building EV-ready properties or property owners installing and offering charging infrastructure to the public.
- Encouraging the use of EV fleets for commercial transportation and deliveries.
- Instituting emissions regulation.
- Free public- access EV charging.
- Ensuring the supply of an integrated charging infrastructure network, with Government taking the first step in the rollout of infrastructure.

What is also evident from these case studies is that it is crucial that a multi-stakeholder approach be taken, incorporating city planners, automotive manufacturers, utilities, infrastructure providers, academic and research institutions, and city and national officials, to collectively identify and address technical, economic and regulatory barriers that may affect the adoption of EVs.

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