ON THE ELECTRICITY DEMAND IN RELATION TO RISE OF ELECTRIC VEHICLES IN MALAYSIA

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Date: 22 May 2018

Statement 1

This thesis is the result of my own investigation, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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I would like to express my sincere gratitude to my beloved supervisor, Mr. Abdul Yamin Saad for his precious encouragement, guidance and generous support throughout this work. The detailed explanation regarding the study from Mr. Yamin was very much appreciated.

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Abstrak

Permintaan untuk kenderaan elektrik semakin pesat di negara maju disebabkan oleh pelbagai faktor. Dengan peningkatan jumlah kenderaan elektrik dan kenderaan hibrid, permintaan untuk tenaga elektrik dijangka meningkat. Pelaksanaan teknologi hijau yang strategik di Malaysia diselidik untuk mengatasi cabaran-cabaran yang akan datang.

Kaedah kuantitatif korelasi digunakan untuk menyelidik faktor-faktor yang mempengaruhi bilangan kenderaan elektrik sekali gus permintaan untuk penjaana elektrik di Malaysia. Penyelidikan ini adalah untuk menunjukkan hubungan atau trend antara faktor-faktor yang mempengaruhi bilangan kenderaan elektrik dan permintaan elektrik. Trend pasaran global bagi kenderaan elektrik juga dikaji dan kaedah regresi digunakan untuk meramal kenderaan elektrik di masa depan.

Kejayaan pelaksanaan kenderaan elektrik juga memerlukan pelan strategik yang dapat dilaksanakan dan dapat dicapai. Penyelidikan ini mengenal pasti teras strategi, sejajar dengan Dasar Teknologi Hijau Negara di mana Kerajaan memainkan peranan penting untuk memacu perubahan untuk mewujudkan ekosistem yang kondusif untuk pembangunan kenderaan elektrik. Penyelidikan ini mengkaji kekuatan dan kelemahan dalam sistem yang sedia ada, dan mencadangkan pelan strategik untuk entiti kerajaan dan / atau sektor swasta yang berkaitan.

Penyelidikan ini adalah penting bagi Malaysia untuk bersedia menghadapi cabaran-cabaran yang boleh membawa kepada negara kita. Pelan strategik untuk mengatasi cabaran-cabaran juga dipertimbangkan dalam penyelidikan ini.

Abstract

The demand for electric vehicles is increasing rapidly in advanced countries due to various factors. With increasing number of fully electric or plug-in hybrid vehicles, a study is done on the demand for electricity in relation to rise of electric vehicles. The strategic green technology implementation to overcome potential challenges in Malaysia is also identified.

A quantitative of correlation method is used to research the key factors affecting the number of electric vehicles against the electricity demand in Malaysia. This research mainly is to indicate the relationship between the factors affecting number of electric vehicles and electricity demand. The trend of the global market for electric vehicles is studied and a regression method is used to determine the future projection modelling of electric vehicles.

The successful implementation of electric vehicles will also require strategic directions that are practicable and achievable. This research identifies strategic thrusts, in line with the National Green Technology Policy where Government's intervention is essential to drive changes in order to create conducive ecosystems for the development of electric vehicles (EV). This research recognises the strengths and weaknesses in the existing system, and provides 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.

Chapter 1 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 CO_2 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 CO_2 emission of 50 g/km. The definition excludes mild hybrid vehicles and full hybrid vehicles.

Table 1.1 Definition of Electric Vehicles (EV)

Types	Definition	Emissions
Battery Electric Vehicle (BEV)	Battery electric vehicles (BEVs), are propelled by an electric motor (or motors) powered by rechargeable battery packs. No other fuel source is used, and there is no internal combustion engine (ICE). EVs require battery charging to power the motor.	0 gCO_2/km
Plug-in Hybrid Electric Vehicle (PHEV)	PHEVs have both an internal combustion engine and electric motor. These vehicles are powered by an alternative fuel or a conventional fuel, such as gasoline (petrol), and a battery, which is charged up with electricity by plugging into an electrical outlet or charging station	50 gCO_2/km

Hybrid Electric Vehicle (HEV)	HEVs powered by both an engine and electricity. HEVs run on fuel alone and do not plug in to an electrical outlet to recharge the battery	90 gCO2/km
Fuel Cell Vehicle (FCV)	FCVs use an electric-only motor like BEVs, but instead of recharging a battery, FCVs store hydrogen gas in a tank. Fuel cell stacks that convert hydrogen gas are stored onboard with oxygen from the air into electricity to drive the electric motor	90 gCO2/km

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.

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).

1.1 Problem Statement

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 BAU (Business as Usual) 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 1.1 BAU scenario of CO2 emissions in Malaysia

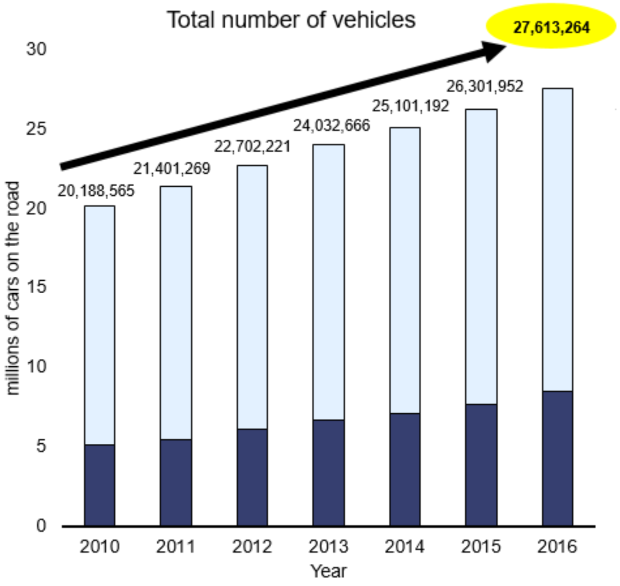

Figure 1.2 Total Registered Motor Vehicles in Malayisa

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.

1.2 Project Background

Electric vehicles (EVs) are propelled by electric traction motors and powered by chemical energy stored in rechargeable batteries. [6] With no carbon dioxide emissions and almost no air pollutants produced, market penetration of EVs is one means through which countries are able to not only achieve higher air quality standards and also collectively stabilise the global climate. In this context, EVs are poised to rapidly turn into a major growth industry and market. EVs are environmentally, fiscally and socially more sustainable than their Internal Combustion Engine (ICE) equivalents.

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.

Besides, this project discusses the environmental, social and economic case for Electric Mobility, and presents the global outlook for the EV sector, as well as international case studies for the adoption of Electric Mobility.

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.

1.3 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 develop a strategy / implementation plan of Electric Vehicles (EV)

1.4 Scope of Work

1. Research and collect data of the global outlook and current outlook in Malaysia
2. Model the benefits of Electric Vehicles (EV) by simple calculation
3. Develop a strategic plan with key initiatives of implementation of Electric Vehicles (EV)
4. Determine the challenges faced by Malaysia in implementation of EV

Chapter 2 Literature Review

In planning for the development of electric mobility in Malaysia, it is important to review the global outlook for Electric Mobility, as well as existing strategies that have been successfully deployed and initiated by countries that have begun to adopt EVs as part of their national transportation policy. This Chapter explores and considers how these might inform policy makers and other stakeholders in the context of Malaysia's needs and policy objectives.

The Chapter presents three Case Studies, of Amsterdam, Los Angeles and Norway, examining policy measures and initiatives these city and national governments have taken to integrate EVs into their transportation landscapes. It also presents an overview of some key policies and incentives set by governments to encourage and support EVs, EV Ecosystems and the EV Economy, as well as selected examples of EV programmes in public transport around the world. Furthermore, this chapter also deep-dives into the charging availability and charging demand for EV charging infrastructure. Clean renewable energy such as solar energy is further studied to present the feasibility of solar panels deployment for EV charging infrastructure.

2.1 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]

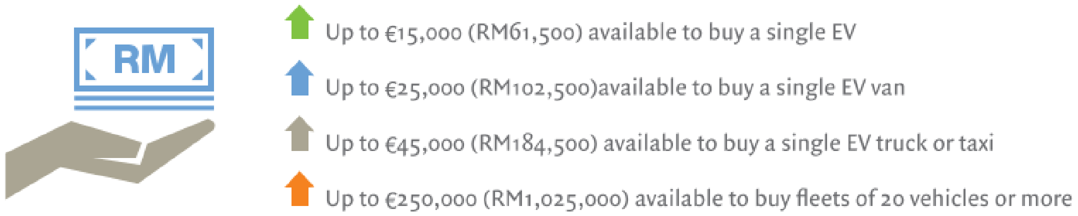

Figure 2.1 EV subsidies (MGTC)

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 at 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 2.2 Lessons learnt from Amsterdam (MGTC)

2.2 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]

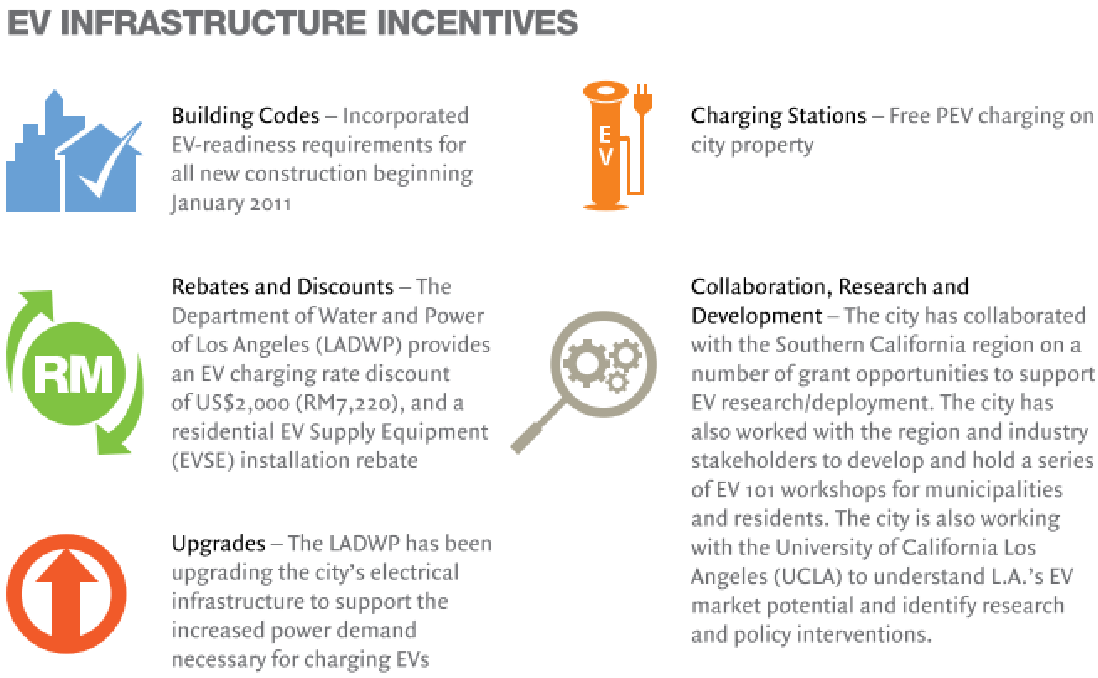

Figure 2.3 EV Infrastructure Incentives (MGTC)

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 2.4 Lessons learnt from L.A. (MGTC)

2.3 International Case Study #3: Norway

Norway has been working to raise awareness about electric vehicles for 30 years, and the results are clear. Public awareness about EVs is high, with most Norwegians being familiar with the different models of EVs available on the market.

Norway has possibly the world's best incentives for Zero Emission Vehicles, and correspondingly the world's highest number of electric cars per capita by a wide margin. However, there was never a grand design or strategy behind this outcome. Rather, it is the result of many small measures adopted over many years to support a growing Norwegian EV industry and to reduce emissions from road transportation. In sum, these incentives have created the world's best EV marketplace.

Norway imposes a car import tax calculated on the basis of a car's CO2 emissions, NOx emissions, and weight. By gradually tuning the system to award cars with low emissions, and penalising cars with higher emissions, the import tax plays a vital role in making low-emission cars attractive to consumers, and thereby achieving the 85 gCO2/km goal.

Norway's 'Green Car' initiative aims to get 200,000 Norwegians to buy a PEV by the year 2020. In order to achieve this goal, Green Car provides hands-on support to corporate and municipal fleets, helping them to successfully introduce EVs where they can match operational and financial requirements. The project also works with OEMs and importers to ensure sufficient supply in the market place, as well as with infrastructure providers.

Posten Norge (Norway Post) was a pioneer in adopting EVs for their delivery fleet as early as 1994. In 2011, Posten Norge joined the Green Goods Transport scheme – a research project to develop more environmentallysound and climate-friendly transport of goods, [15] and signed up for 20 new electric cars. Ford Transit Connect Electric has been developed in collaboration with Norway Post. In 2015, Posten Norge aims to replace 1,300 fossil-fuel cars with electric cars and other alternative vehicles. [15]

Norway also introduced Taxi Trondheim, a collaboration between taxi operators Trøndertaxi and Stjørdal taxi, the utility company NTE, the municipality of Trondheim and Transnova. From 2011 to 2013, six Nissan LEAFs were deployed in regular taxi services in the Trondheim area. Supported by three fast chargers, the aim was to uncover practical and economical benefits and limitations associated with EV taxis. The project also cooperated with Nissan in order to secure log data from the 6 LEAFs, which provided detailed information on energy consumption in different topologies and climate conditions. [16]

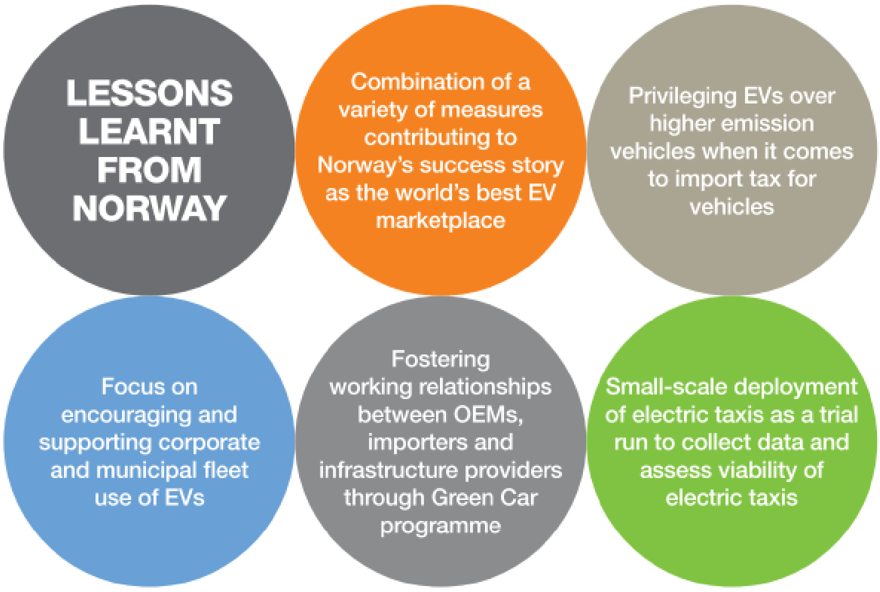

Figure 2.5 Lessons learnt from Norway (MGTC)

2.4 Global outlook: Current national policy incentives

National policy incentives currently practiced by leading EV markets are as follows: [17]

Table 2.1 Current national policy incentives

EVI Members	Financial	Infrastructure	RD&D
China [18]	Purchase subsidies for vehicles of up to RMB60,000	-	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)
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,	The UK Technology Strategy Board has identified 60

		railway and public sector locations. Available until 2015	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

2.5 Operating Reserve

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. [30]

Table 2.2 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 10 minutes 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 2.3 Operating reserve requirement

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

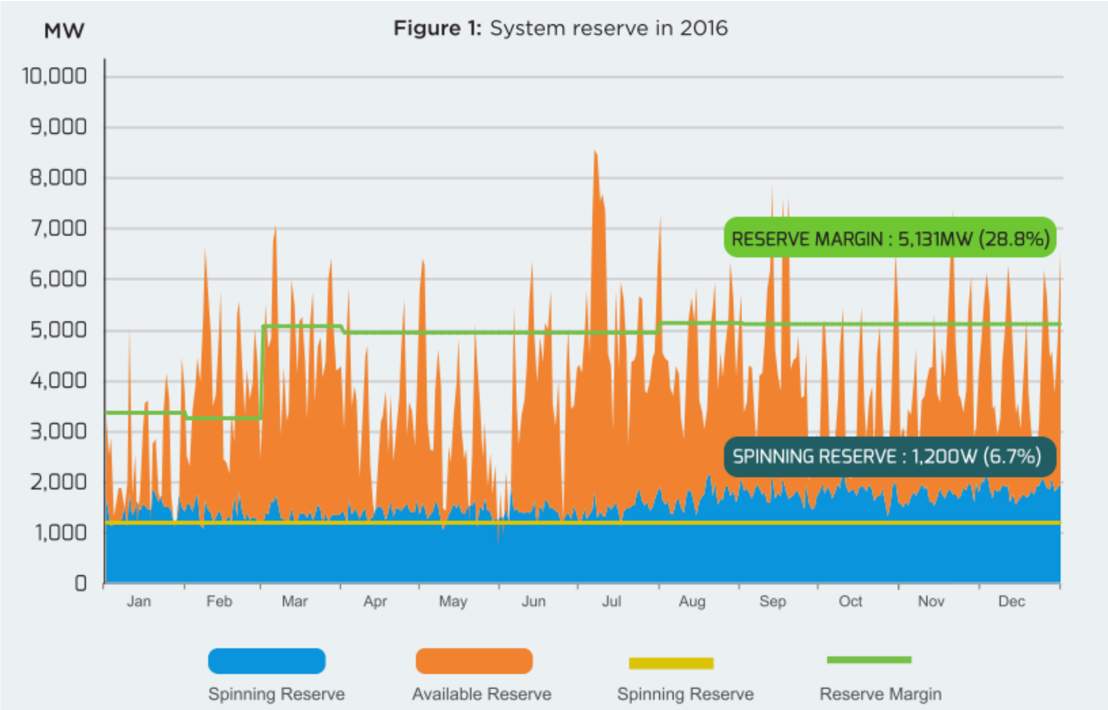

Figure 2.6 System reserve in 2016 (NEB)

2.6 Reserve Margin

The main reason for the prevalent use of reserve margin as a reliability criteria 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 considered to 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]

2.7 Renewable Energy for EV

2.7.1 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.

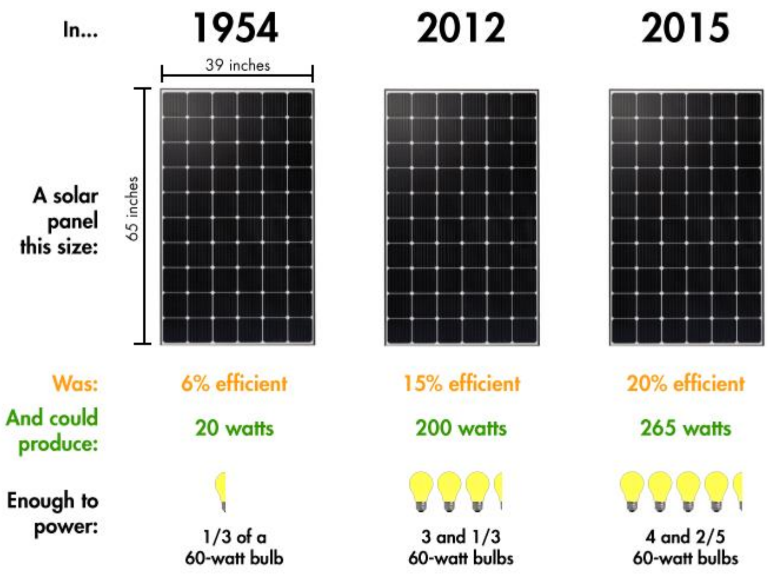

Figure 2.7 History of solar panels

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%.

2.7.2 Solar energy system

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.

The vast majority of 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 are used than the solar panels have generated, more have to be paid to the utility. This process is known as net energy metering.

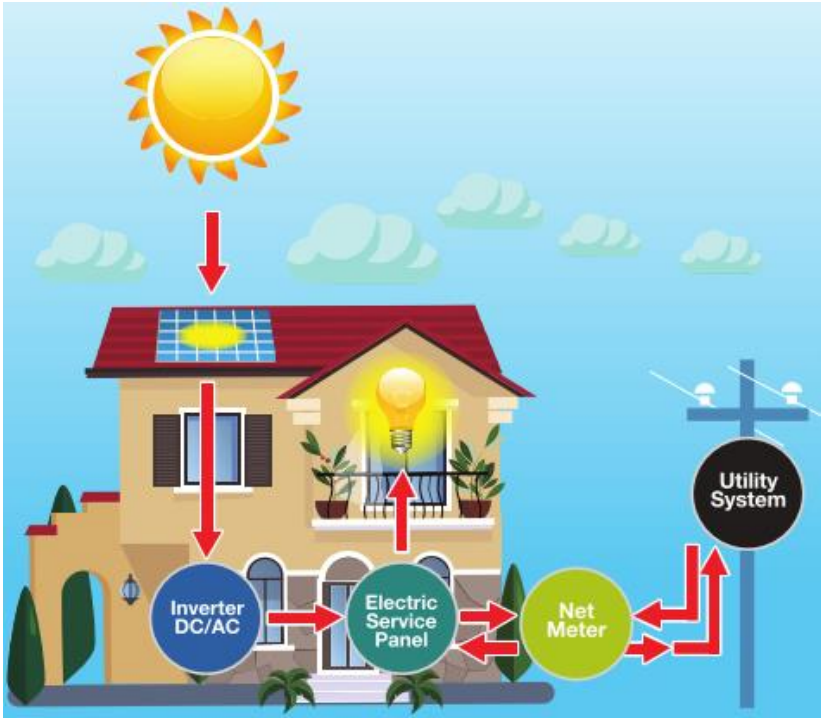

Figure 2.8 NEM interconnection to utility system (NEB)

2.7.3 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 Honorable 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]

2.7.4 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.

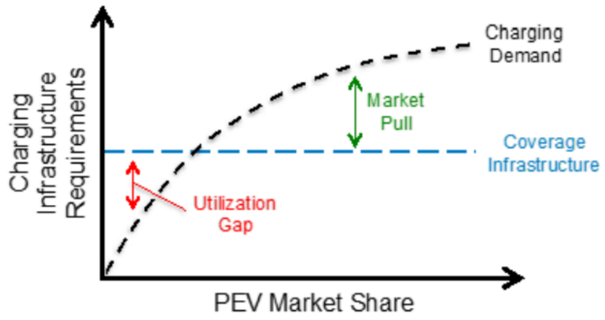

Figure 2.9 PEV charging requirements evolution as a function of PEV market share

Figure *2.9* 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]

2.7.5 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 behavior of many calendar days of data simultaneously.

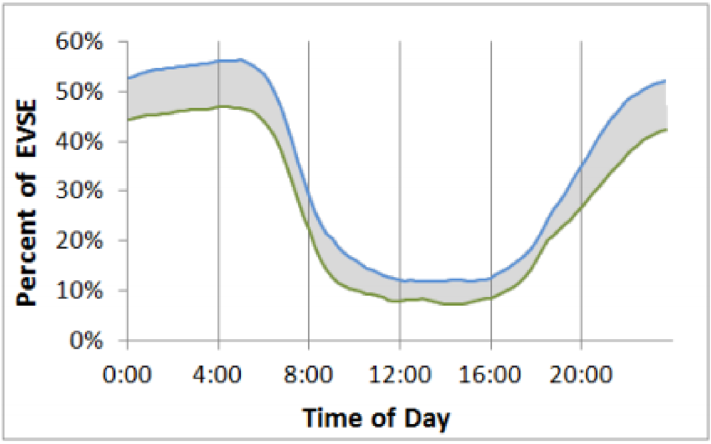

Figure 2.10 Weekday time-of-day charging

2.7.6 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.

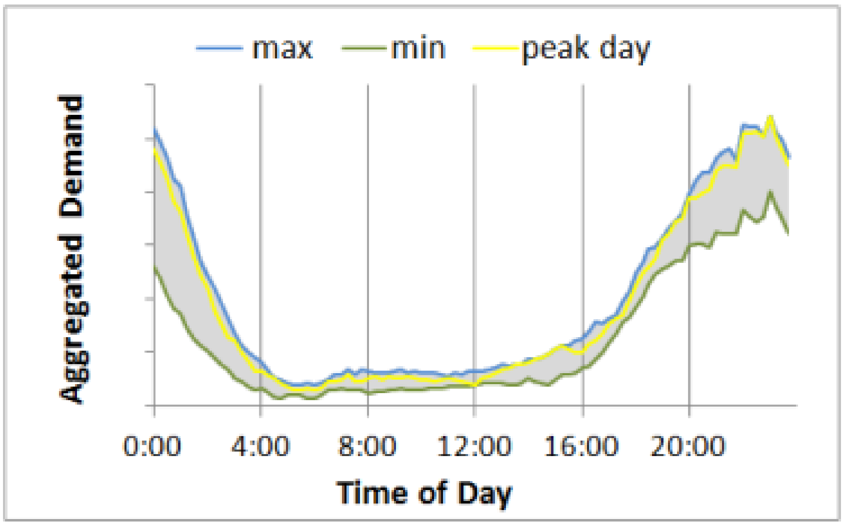

Figure 2.11 Time-of-day demand plot with peak day

Chapter 3 Methodology

Correlation and regression are techniques for investigating the statistical relationship between two, or more, variables. They fill the gaps: the strength of the relationship between two (or more) ratio scale variables can be measured and the significance tested.

Correlation and regression are the techniques most often used by economists and forecasters. They can be used to answer such questions as

- Is there a link between the electric vehicles supply and the price level?
- Does electricity demand increase in relation to the increasing number of population?
- Does insufficient of infrastructure in a country hinder electric vehicles growth?

Each of these questions is about economics or business as much as about statistics. The statistical analysis is part of a wider investigation into the problem; it cannot provide a complete answer to the problem but, used sensibly, is a vital input. Correlation and regression techniques may be applied to time series or cross-section data. The methods of analysis are similar in each case, though there are differences of approach and interpretation. [34]

3.1 Correlation and causality

It is important to test the significance of any result because almost every pair of variables will have a non-zero correlation coefficient, even if they are totally unconnected (the chance of the sample correlation coefficient being exactly zero is very, very small). Therefore it is important to distinguish between correlation coefficients which are significant and those which are not, using the t test just outlined. But even when the result is significant one should beware of the danger of 'spurious' correlation. Many variables which clearly cannot be related turn out to be 'significantly' correlated with each other. [34]

3.2 Regression Analysis

Regression analysis is a more sophisticated way of examining the relationship between two (or more) variables than is correlation. Regression analysis describes this causal relationship by fitting a straight line drawn through the data, which best summarises them. It is sometimes called 'the line of best fit' for this reason. The major differences between correlation and regression are the following:

- Regression can investigate the relationships between two or more variables.
- A direction of causality is asserted, from the explanatory variable (or variables) to the dependent variable.
- The influence of each explanatory variable upon the dependent variable is measured.
- The significance of each explanatory variable can be ascertained.

Thus regression permits answers to such questions as:

- Does the population growth rate influence electric vehicles' growth rate?
- If the growth rate increases, by how much might the electric vehicles' growth rate be expected to fall?
- Are other variables important in determining the growth rate?

3.3 Correlation and P-value Calculation

The calculation was based on Pearson correlation method which the formula is:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Equation 1

r = +/-0.5 consider as large effect

r = +/-0.3 consider as medium effect

r = +/-0.1 consider as small effect

3.4 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 behavior 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]

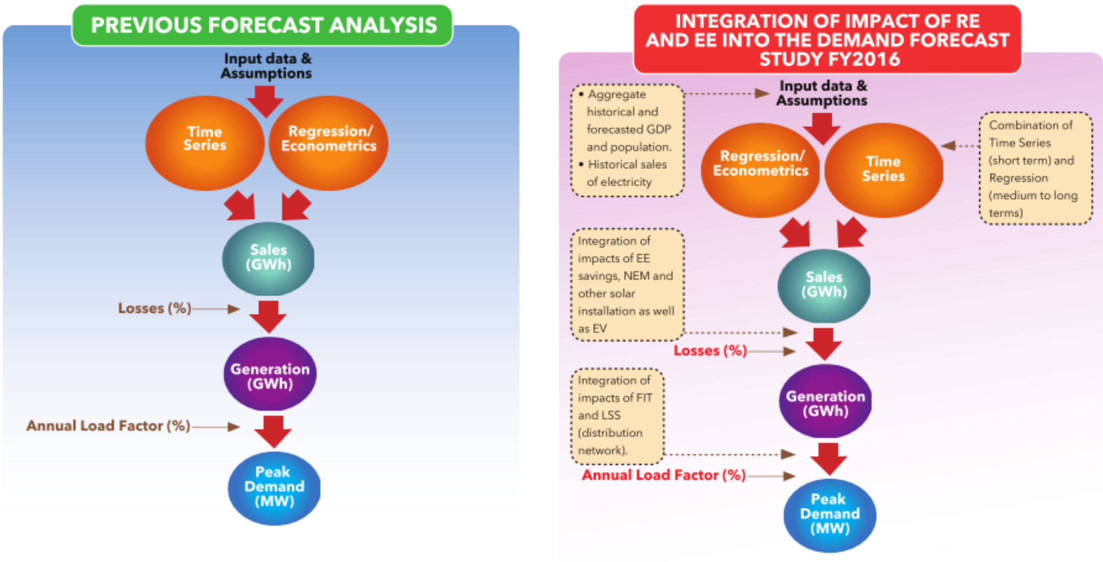

Figure 3.1 Demand forecast study methodology (NEB)