A SOLAR ENERGY BASED ELECTRIC VEHICLE CHARGING INFRASTRUCTURE FOR SHOPPING CENTRE

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ABSTRACT

Among the numerous climate change concerns confronting our society, one of the most critical is lowering emissions from road transportation. Electric vehicles (EVs) are vital aspects in efforts to reduce CO2 emissions and improve air quality in urban areas. However, charging infrastructure is required to enable the transition from internal combustion engines (ICEs) to electric vehicles.To convince consumers to change to electric vehicles, Malaysia's government has declared in its 2022 national budget that EVs would be totally tax-free upon import, excise duty, and all other taxes. Making them more affordable is critical, but so is assuring their functionality.The study's objective was to develop the most appropriate model for enhancing the renewable energy system for EV charging stations located in shopping centres' parking lots in order to maximise electric power and carbon savings. The parking area of the IOI City Mall has been turned into public charging area and a solar farm. The simulations were conducted utilising the main five EV charging stations, which can accommodate 690 vehicles per month. The simulation consists of 4 main models. Each model corresponds to a different battery capacity: S, M, L, and XL. Each case was simulated twice: on a sunny day and on a gloomy day. The HOMERpro programme is used to determine the system's potential and the capacity of the generated electricity.The findings indicate that it is feasible to utilise the carparks of Malaysian shopping centres as a solar power plant for off-grid EV charging stations. The simulation of an unfulfilled electrical demand indicates the feasibility of the designed-solar panel installation. The electricity generated is sufficient to power the EV charging stations. On-site renewable energy (RE) generation for EV charging stations enables both cost savings and CO2 reductions associated with power generation.

ABSTRAK

Di antara pelbagai kebimbangan perubahan iklim yang dihadapi oleh masyarakat kita, salah satu yang paling kritikal ialah mengurangkan pelepasan daripada pengangkutan jalan raya. Kenderaan elektrik (EV) adalah aspek penting dalam usaha mengurangkan pelepasan CO2 dan meningkatkan kualiti udara di kawasan bandar. Walau bagaimanapun, infrastruktur pengecasan diperlukan untuk membolehkan peralihan daripada enjin pembakaran dalaman (ICE) kepada kenderaan elektrik.Untuk meyakinkan pengguna untuk menukar kepada kenderaan elektrik, kerajaan Malaysia telah mengisytiharkan dalam belanjawan negara 2022 bahawa EV akan bebas cukai sepenuhnya atas import, duti eksais dan semua cukai lain. Menjadikannya lebih berpatutan adalah penting, tetapi begitu juga dengan memastikan kefungsian mereka.Objektif kajian adalah untuk membangunkan model yang paling sesuai untuk meningkatkan sistem tenaga boleh diperbaharui untuk stesen pengecas EV yang terletak di tempat letak kereta pusat beli-belah untuk memaksimumkan penjimatan tenaga elektrik dan karbon. Kawasan parkir IOI City Mall telah dijadikan kawasan pengecasan awam dan ladang solar. Simulasi itu dijalankan menggunakan lima stesen pengecas EV utama, yang boleh memuatkan 690 kenderaan sebulan. Simulasi terdiri daripada 4 model utama. Setiap model sepadan dengan kapasiti bateri yang berbeza: S, M, L dan XL. Setiap kes disimulasikan dua kali: pada hari yang cerah dan pada hari yang suram. Program HOMERpro digunakan untuk menentukan potensi sistem dan kapasiti tenaga elektrik yang dijana.Penemuan menunjukkan bahawa adalah wajar untuk menggunakan tempat letak kereta pusat beli-belah Malaysia sebagai loji tenaga solar untuk stesen pengecas EV luar grid. Simulasi permintaan elektrik yang tidak dipenuhi menunjukkan kebolehlaksanaan pemasangan panel solar yang direka bentuk. Tenaga elektrik yang dijana adalah mencukupi untuk menghidupkan stesen pengecas EV. Penjanaan tenaga boleh baharu (RE) di tapak untuk stesen pengecas EV membolehkan penjimatan kos dan pengurangan CO2 yang dikaitkan dengan penjanaan kuasa

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LIST OF ABBREVIATIONS

AC	-	Alternative current
BEV	-	Battery electric vehicle
DC	-	Direct current
EV	-	Electric vehicle
EVSE	-	Electric vehicle supply equipment
HEV	-	Hybrid electric vehicle
LiON	-	Lithium-Ion
PHEV	-	Plug-in hybrid electric vehicle
SOC	-	State of Charge

LIST OF SYMBOLS

δ	-	Minimal error
D, d	-	Diameter
F	-	Force
v	-	Velocity
p	-	Pressure
I	-	Moment of Inertia
r	-	Radius
Re	-	Reynold Number

CHAPTER 1

INTRODUCTION

1.1 Background

Recently, speculation of a new national automobile project has spread throughout Malaysia. These disputes were prompted by Prime Minister Tun Dr Mahathir Mohamad's, in which he proposed that Malaysia establish a national automotive firm with the goal of competing in international markets. The public reaction to the potential of a third local manufacturer after Proton and Perodua has been split, with some believing that efforts should be directed into public transportation instead. They make an excellent point, emphasising the need of increasing the accessibility and availability of public transit options in Malaysia, as well as encouraging their use.

Malaysia has the highest motorization rate among ASEAN nations in 2015, at 439 automobiles per 1,000 population, more than four times the continental average. Another national automotive effort, by ostensibly growing the vehicle fleet, would increase traffic congestion, which is already a significant issue in Malaysia's booming metropolitan regions. Notably, it would very certainly thwart any attempt to eliminate transportation-related emissions.

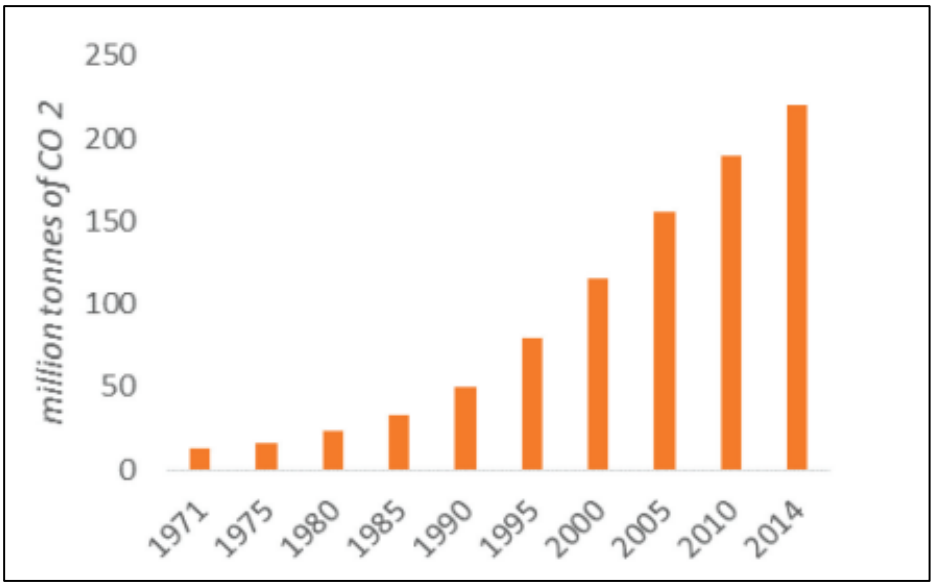

Figure 1.1 The trajectory of national emissions, measured in CO2

Between 1971 and 2014, Figure 1.1 illustrates the history of national emissions, measured in CO2-equivalent (CO2e) emissions from transportation. Emissions more than doubled during this time span, reaching 65MtCO2e. In 2012, road transport accounted for over 85% of transport emissions, with cars and motorbikes accounting for nearly 70%, or 38.7MtCO2e. There is great potential for major climate action within this energy sub-sector, but it is improbable to be achieved with increased car ownership in Malaysia (SEDA, 2018).

Ever since, attention has switched to the concept of a national electric car initiative, fuelled by concerns about climate change and automotive sector trends indicating a future of electrified – and eventually self-driving – vehicle fleets. Late in July, the Malaysian Green Technology Corporation also known as GreenTech Malaysia, a MESTECC-accredited organisation, announced that it is now developing a national electric vehicle proposal that will be submitted to the Ministry for permission at a future date.

In light of this, this research serves as a reminder to GreenTech Malaysia, MESTECC, and other key government stakeholders that electric vehicles (EVs) are only as clean as the energy sources that power them, with emissions being transferred from the tailpipe to the smokestack. Malaysia generates about 90% of its electricity from the burning of fossil fuels; As a consequence, concentrating entirely on EVs without addressing the country's energy grid composition would be premature and would almost certainly result in an increase in the country's transportation sector emissions. This would be a tragedy in light of Malaysia's pledge to reduce GHG emissions by 45 percent by 2030, especially given that transportation should be a low-hanging fruit in terms of overall national emissions reductions.

This research serves as a reminder to government stakeholders that electric vehicles (EVs) are only as pure as the energy sources that power them, with emissions being transported from the smokestack to the tailpipe. Malaysia produces more than 90% of its electricity from fossil fuel burning; consequently, focusing only on EVs without first addressing the country's energy grid structure would be hasty and virtually probably result in higher mobility sector emissions. This would be a disaster considering Malaysia's commitment to decrease GHG emissions by 45 percent by 2030, this is especially true considering that transportation should be a low-hanging fruit in terms of the broader national effort to reduce emissions.

Malaysia is establishing itself as a market economy in the modern era. Malaysia's GDP growth rate is one of the most competitive in the world; in 2019-2020, it increased at a 7.2 percent annual rate, placing it 20th globally, ahead of countries such as New Zealand and Australia. Malaysia is the world's largest producer of tin and rubber. According to ERIA (Economic Research Institute for ASEAN and South Asia), the country launched a National Green Technology policy to support the EV market and also developed the GreenTech Malaysia plan, which states that by 2020, 100,000 passenger electric vehicles, 2000 bus electric vehicles, and 100,000 electric motorcycles or scooters will be available on national roads.

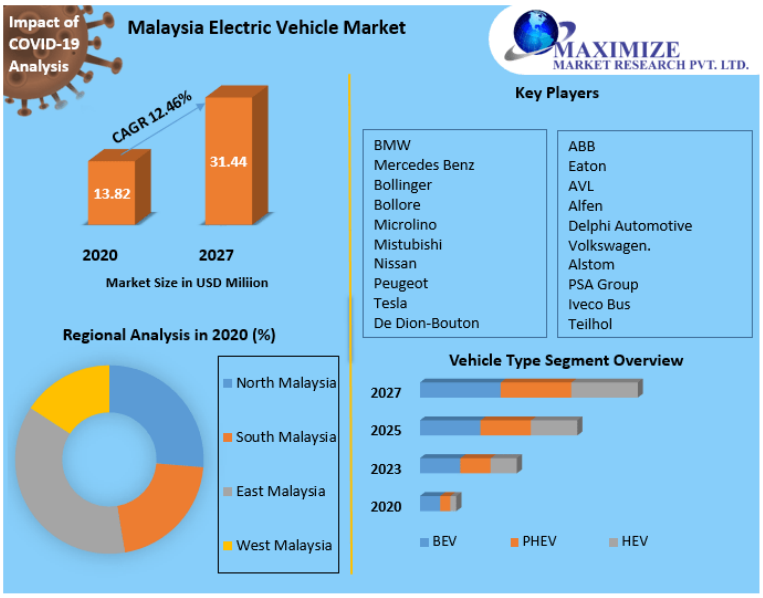

Figure 1.2 Malaysia Electric Vehicle Market Overview

Based on Figure 1.3, the market is sub-segmented into Two-wheeler, Passenger vehicle, and Commercial vehicles. The passenger vehicle leading the Malaysia electric vehicle market in 2020. When compared to its nearest neighbour, Singapore, Malaysia was the first to introduce electric buses (ResearchAndMarkets.com's)

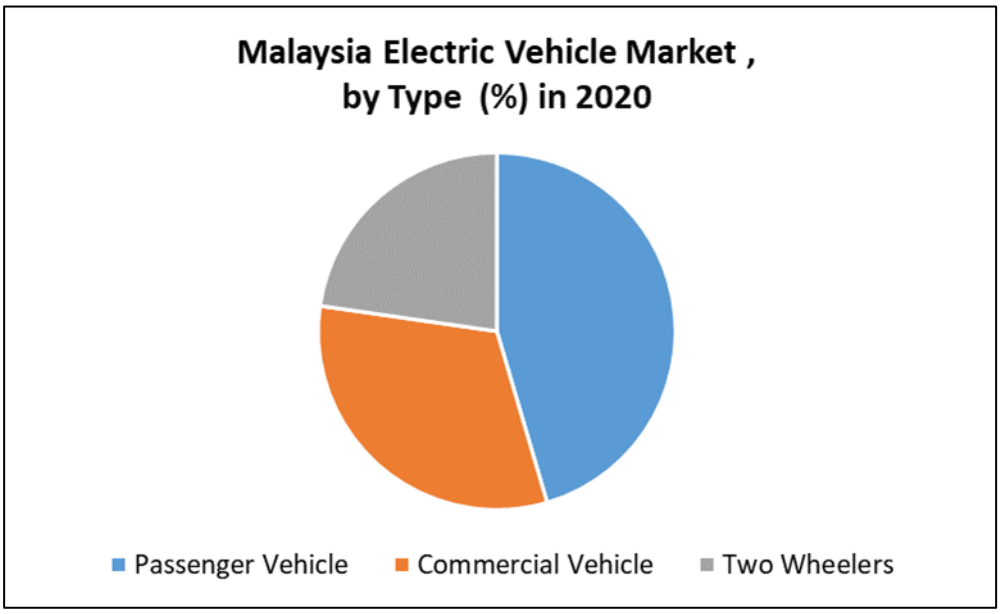

Figure 1.3 Malaysia Electric Vehicle Market by Type in 2020

1.2 Problem Statement

However, using EVs increases the amount of electricity required to power the EV's battery. Demand increases not just the national grid's generating capacity, but also the level of emissions produced by coal, petroleum, and other non-renewable sources of energy, which are the primary sources of power in Malaysia. The charging demand has increased as a result of the fact that the majority of automobile owners frequently charge their batteries virtually simultaneously. The increased demand has an effect on grid generation, which utilizes a variety of energy resources in the existing energy mix. As a result, power must be generated as quickly as possible to meet demand during peak periods (Autovista Group, 2017).

The combination of smart charging stations and internet of things (IOT) technologies is considered as a vital component in resolving these difficulties. Charge times may be managed during peak load periods, and carbon content can be restricted when it reaches an excessively high level (Cutting, 2019). Another option for addressing the EV fleet demand issue is to isolate the system by establishing an off-grid renewable energy system at the charging stations.

Due to the aforementioned technological obstacles, a case study was conducted to determine technical solutions for the demand of electric vehicles, grid connectivity, and the grid's high carbon intensity. The most appropriate size of model has been chosen to optimize the renewable energy system for EV charging stations in order to achieve the greatest possible energy and carbon savings. The Putrajaya Shopping Centre's parking lot has been converted into charging stations and a solar farm. The HOMERGrid program was used to model the power response of the complete electrical load served, the full quantity of solar energy generated, the battery input power, and the grid power generated. Thus, EVs will achieve zero-emission status in terms of both their driving technology and the resources utilised to power them.

1.3 Research Objectives

The following objectives are established in order to achieve the goal:

a) Develop a scale model of the renewable energy system using HomerPro that provides an appropriate supply of electricity for the EV charging stations in the parking lot.

b) Simulate the modelling system using EV demand profiles for a variety of scenarios and settings.

1.4 Research Scopes

The study's scope has been defined as follows:

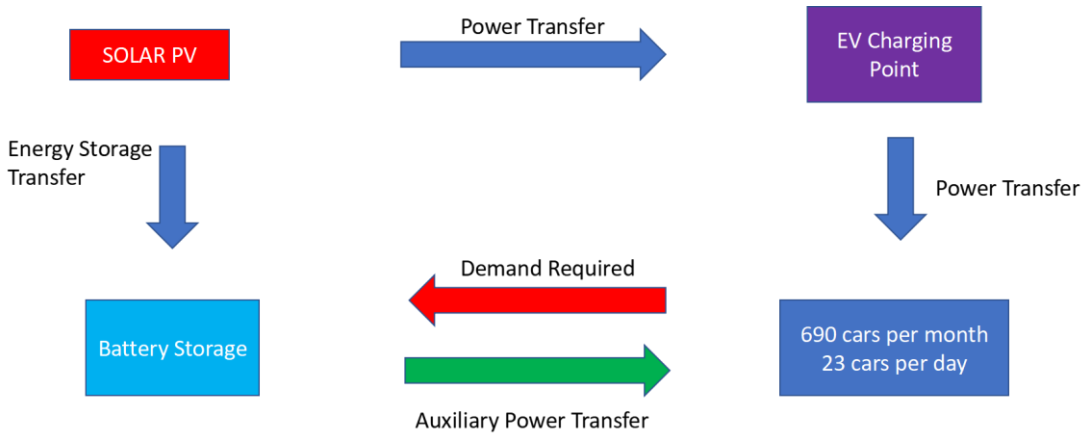

Figure 1.4 The schematics of the solar off-grid parking system

a) Electric Vehicles Analysis (EVs): The study examines and concentrates on Battery Electric Vehicles (BEVs), which are powered by electric batteries, such as those seen in the Tesla Model S and Nissan Leaf.

b) EV Charging Stations (EVSE): The EV charging station in this research refers to the charging points located within and outside the Putrajaya Shopping Centre's parking lot. The simulations were run using 10 EV charging stations and a monthly capacity of 690 automobiles.

c) Renewable Energy Technology: Renewable energy used in this study as refer to a solar energy off-grid system that powers the electric vehicle charging points located in the Putrajaya Shopping Centre's parking lot.

Due to various uncontrolled variables, the following concerns are not considered in the scope of the research.

a) Additional EV models include hybrid vehicles (HEVs) and plug-in hybrids (PHEV).
b) Technical assessment of the EVSE's power circuit; bidirectional converter and battery storage selection.
c) Feed-in tariffs and policies for the national grid, which are politically controversial in Malaysia

1.5 Significance of Study

There are many problems that electric vehicle (EV) owners currently face. Range anxiety, which is the fear that drivers have when the battery charge is low and a charging station is unavailable, is a major one in Malaysia. Some EV owners face pushback from high-rise building owners that do not let them install a charging station in the building. For aspiring EV owners, the steep prices of these vehicles are a hurdle. Those who are concerned about environmental issues may also be turned off by the fact that Malaysia’s electricity is still mainly generated from fossil fuels.

This research will determine the feasibility scale model of the renewable energy system that provides an appropriate supply of electricity for the EV charging stations in the parking lot. This study will also provide opportunity on optimization of hybrid combination of energy system in Malaysia. To propose an effective hybrid fusion design, a device is necessary to assure that the study’s objectives are met. HOMER was chosen as the software for this project as it can assist in optimizing hybrid combination designs and provides emissions and cost statistics pertaining to

situations. Furthermore, this will help to achieve the objective in a more systematic approach.

This tool can immensely aid the government and policy maker to determine and optimized operating strategy despite the dynamic process changes. At the end, reduction in operating cost will contribute to bottom-line of profitability. The energy industry has been more challenging as ever with the electrical price volatility, increase in energy & non-energy cost and stringent directive from authorities thus surviving in a thin margin environment require innovation and creativity that could be achieved through this research

REFERENCES

Alternative Fuel Data Center, (2020). *How does Electric Vehicle work*? [online] Available at: https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work [Accessed 20 May 2020].

Autovista Group, (2017). *EVs risk serious damage to UK power network if just a handful charge on one street*. [online] Available at: https://www.autovistagroup.com/news-and- insights/evs-risk-serious-damage-uk-power-network-if-just-handful-charge-one-street-report [Accessed 24 May 2020].

Battery University, (2016). *BU-903: How to Measure State-of-charge*. [online] Available at: https://batteryuniversity.com/learn/article/how_to_measure_state_of_charge [Accessed 18 May 2020].

Battery University, (2016). *EVs battery*. [online] Available at: http://batteryuniversity.com/learn/article/electric_vehicle [Accessed 18 May 2020].

Centsy Company, (2020). *40 Watt Solar Panel Specification*. [online] Available at: https://www.centsys.com.au/ [Accessed 24 May 2020].

Choma, E. (2015). Environmental impact assessment of increasing electric vehicles. *Science direct*, 13(5), pp. 497-507.

Clean Solar Company, (n.d.). *The solar power system*. [online] Available at: https://www.cleanenergyreviews.info/blog/2014/5/4/how-solar-works [Accessed 24 May 2020].

Cutting, E. (2019). *The Development of Carbon conscious in EV Charging Model*. [online] Available at: https://developmentccevmodel.wixsite.com/developmentccevmodel [Accessed 25 May 2020].

EGAT, (2019). *Solar photovoltaic output depends on orientation, tilt, and tracking*. [online] Available at: https://www.egat.co.th/ [Accessed 23 May 2020].

Electric Vehicle Database, (2019). *Global EVs Data Base*. [online] Available at: https://ev- database.org/ [Accessed 21 May 2020].

EVs Specification, (2020). *A Full Database of Global EVs Model updated*. [online] Available at : https://www.evspecifications.com/ [Accessed 21 May 2020].

Falvo, N. (2014). EV Charging Stations and Modes: International Standards. *Research Gate*, 5(6), pp. 22-37.

Fomm Electric Vehicles, (2020). *Fomm one Model Specification*. [online] Available at: https://fomm.co.th/th/ [Accessed 22 May 2020].

Full Solar Company, (2020). *100–140-Watt Solar Panel Specification*. [online] Available at: www. Fullsolar.co.th [Accessed 21 May 2020].

Govidhayawong, P. (2016). Integrating Renewable Energy Systems for Off-grid Electric Vehicle Charging Station on Motorway, *University of Strathclyde*, 3(1), pp. 10-75.

Hannan, M. (2018). State-of-the-Art and Energy Management System of Li-on Batteries in Electric Vehicle. *IEEE*, 43(5), pp. 19-36.

Homer Energy, (2015). *The World's Leading Microgrid Modelling Software*. [online] Available at: http://www.homerenergy.com/software.html. [Accessed 26 May 2020].

IEC International Standard, (2011). *New standards move international EV cross-market compatibility forward*. [online] Available at: https://www.iec.ch/newslog/2011/nr1511.htm [Accessed 24 May 2020].

Kgsolar, (2020). *The solar panel Mono VS Poly*. [online] Available at: http://www.blueconcept.co.th [5 June 2020].

Kia Co. ltd., (2020). *Kia E-Soul Model Specification*. [online] Available at: https://www.kia.com/th/showroom/new-soul-ev/features.html [Accessed 23 May 2020].

KRUNGSRI RESEARCH, (2018). *Power Generation*. [online] Available at: https://www.krungsri.com/bank/getmedia/b2bac10f-ff94-4865956121f7d15e4dc6/IO_Power_Generation_190627_EN_EX

Kuehn, T. H. and Ramsey, J. W. (2009). *Appendix D. In: Thermal Environmental Engi*

Malaysia Government, (2017). *National Electric Mobility Blueprint* [online] Available at: https://rise.esmap.org/data/files/library/malaysia/RE/12.4%20page%2011.pdf

Mary Land EV, (2020). *Type of EV charger*. [online] Available at: https://marylandev.org/charging/ [Accessed 22 May 2020].

Masters, G. M. (2004). *Renewable and Efficient Electric Power Systems*. New Jersey: John Wiley & Sons, Inc.

Mordor intelligent - ELECTRIC VEHICLE CHARGING STATION MARKET, GROWTH,

Morton, C., Grant, A. and Kim, J. (2014). *An Investigation into the Specification of an Off- Grid Hybrid Wind/Solar Renewable Energy System to Power an Ecobarn Building*. [online] Available at: http://www.esru.strath.ac.uk/Programs/Merit/case_study_Ecobarn.pdf. [Accessed 26 May 2020].

NASA's Surface Solar Energy Data, (2020). *Solar Radiation Data*. [online] Available at: https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/ [Accessed 19 May 2020].

neering Laboratory. s.l.: University of Minnesota, pp. D-7.

Nissan Co. ltd, (2020). *Nissan Leaf Model Specification*. [online] Available at: https://www.nissan.co.th/vehicles/new-vehicles/leaf.html [Accessed 18 May 2020].

Ostergaard, P. A. (2015). Reviewing EnergyPLAN simulations and performance indicator applications in EnergyPLAN simulations. *Applied Energy*, 154, p. 921-933.

REN SMART, (2019). *CO2 emissions due to electricity generation*. [online] Available at: https://www.rensmart.com/Calculators/KWH-to-CO2 [Accessed 18 May 2020].

RETScreen, (2015). *RETScreen international Empowering Cleaner Energy Decision*. [online] Available at: http://www.retscreen.net/ang/home.php. [Accessed 23 May 2020].

RF Wireless World, (2019). *EV Charging Modes*. [online] Available at: https://www.rfwireless-world.com/Terminology/EV-charging-modes.html [Accessed 20 May 2020].

Solar Tron Company, (2020). *250–300-Watt Solar Panel Specification*. [online] Available at: www.solartron.com [Accessed 27 May 2020].

Sustainable Energy Development Authority. (SEDA) Malaysia

Szokolay, S. V. (2007). *Solar Geometry*. ISBN 0 86766 634 4 ed. Brisbane: The University of Queensland.

Tesla Co. ltd, (2020). *Tesla Model S Model Specification*. [online] Available at:

https://www.tesla.com/ [Accessed 23 May 2020].

TRENDS, AND FORECASTS, (2020). *EVs charging station market*. [online] Available at: https://www.mordorintelligence.com/industry-reports/electric-vehicles-charging-stations- market [Accessed 25 May 2020].

Viana, L. (2017). Modelling and Analysis of a Photovoltaic System on a Car Park as Energy Source for Electric Vehicle Charging. *Research Gate*, 2(4), pp. 10-32

Wu, C., Wang, Y., Liu, S. and Xu, H. (2008). *Study on Automatic Sun-tracking Technology in PV Generation*. Nanjing, China, IEEE.

Younghein, M. and Martinot, E. (2015). Beyond 33% Renewables: Grid Integration Policy for a Low-Carbon Future. *CPUC Energy,* 13(9), pp. 33-80.

https://www.tnb.com.my/assets/annual_report/TNB_IAR_2020.pdf

https://www.tnb.com.my/assets/newsclip/Utusan__Cas_pantas_kenderaan.pdf