ON THE DEMAND OF ELECTRIC VEHICLES IN MALAYSIA AND ITS POTENTIAL: STATISTICAL ANALYSIS

SAIFUL ANWAR BIN SUHAIMI

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By:

SAIFUL ANWAR BIN SUHAIMI

(MATRIX NO.: 135973)

Supervisor:

MR. ABDUL YAMIN SAAD

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DECLARATION

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

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LIST OF ABBREVIATIONS

ICE	Internal Combustion Engines
EV	Electric Vehicles
BEV	Battery Electric Vehicles
PHEV	Plug-In Hybrid Electric Vehicles
HEV	Hybrid Electric Vehicles
CO2	Carbon Dioxide
CO	Carbon Monoxide
IPCC	International Panel for Climate Change
IEA	International Energy Agency
kWh	Kilowatt-hour
NOx	Oxides of Nitrogen
uHCs	Unburnt Hydrocarbons
USM	Universiti Sains Malaysia

ABSTRAK

Kenderaan elektrik telah wujud sejak awal abad ke-20, namun begitu, hanya 5% kenderaan di seluruh jalanan di dunia dikuasai oleh eletrik ataupun dikuasai oleh sistem hibrid elektrik. Kenderaan yang menggunakan enjin pembakaran dalaman (ICE) sudah dianggap ketinggalan zaman; ianya mempunyai tahap efisiensi yang rendah, menggunakan banyak bahan api, dan menghasilkan pelepasan berbahaya. Namun begitu, masyarakat umum lebih gemar menggunakan kenderaan yang dilengkapi ICE kerana ianya lebih mudah digunakan, ianya juga lebih murah berbanding kenderaan elektrik, dan infrastruktur elektrik masih ketinggalan dan ianya sukar diakses oleh masyarakat umum. Oleh itu, kajian ini bertujuan untuk menentukan permintaan serta potensi kenderaan elektrik di peringkat pasaran global. Kajian ini juga akan mengembangkan lagi tentang kebaikan serta keburukan kenderaan elektrik berbanding kenderaan yang menggunakan enjin pembakaran dalaman. Kajian ini akan mengumpul data daripada pelbagai badan pentadbiran antarabangsa serta tempatan, kajian ini bertujuan untuk meramalkan perkembangan sektor kenderaan elektrik pada masa hadapan. Tambahan pula, kajian ini juga bertujuan bagi menentukan pelepesan gas berbahaya yang bakal dikurangkan sekirnya populasi umum bermula menggunakan kenderaan elektrik. Dengan mengumpul data ke dalam perisian seperti Simulink, kajian ini berjaya mewujudkan model ramalan yang memetakan stok serta jualan kenderaan elektrik, serta anjakan bahan bakar serta pelepasan gas CO2 pada masa hadapan.

Kata kunci: Kenderaan Elektrik, Enjin Pembakaran Dalaman (ICE), Perkembangan Sektor Kenderaan Elektrik, Model Ramalan, Stok dan Jualan, Anjakan Bahan Bakar.

ABSTRACT

Electric vehicles exist since the early 20th century, however only around 5% of current vehicles globally are powered by an electric drivetrain or a hybrid of an electric drivetrain. Vehicles which uses internal combustion engines (ICE) are deemed outdated; they have low efficiency, consume a lot of fuel and produce harmful emissions. However, the general population still prefer ICE vehicles because they are more accessible, generally cheaper and the electric vehicle infrastructure is very primitive which means that they are still inaccessible to the majority of the general population. Limited EV infrastructures such as charging stations are one of the main reasons why EVs are not the main transportation system in our society today. Therefore, this study aims to mainly determine the demand and potential of electric vehicles in the global market. This study will further expand upon the advantages as well as disadvantages of electric vehicles in comparison to vehicles using internal combustion engines. This study will be compiling data from various governmental bodies, both international and local, this study aims to predict the growth of the electric vehicle sector in the near future. Moreover this study also aims to properly determine the emmissions that will be removed if the general population start to transition into using electric vehicles. Using an external simulation software such as Simulink, this study is able to create a predictive model that maps out the electric vehicle stock and sales, as well as oil displacement and CO2 emission equivalence in lieu of using electric vehicles as to using internal combustion engines.

Keywords: Electric Vehicles (EV), Internal Combustion Engines (ICE), Electric Vehicle Sector Growth, Predictive Model, Stock and Sales, Oil Displacement

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In this research, data will be collected from pre-existing papers, and research journals that highlights the general advantage and disadvantage of electric vehicles (EVs), expanding upon their performance, efficiency and their carbon footprint in comparison to traditional internal combustion engine vehicles. With said data collected from pre-existing papers, this study intends to further study the adoption and acceptance rate of Malaysians towards EVs in general, highlighting the demand and their potential.

In a developing country like Malaysia, transportation is a very important aspect in everybody's lives. Almost everyone in Malaysia uses some sort of transportation one way or another, be it a personal vehicle, like a car, or public transportation like the bus, the train or the light rail transit (LRT). The increasing amount of vehicles on the road has led to many problems towards Malaysians in general as well as towards the atmosphere and air quality specifically. The more number of vehicles on the road, the higher the air pollution that is released into the atmosphere. A study has shown approximate 214,427 kg of air pollutants are emitted by private cars in Kuala Lumpur in the year 2014 alone [1].

Vehicles that employ internal combustion engines, uses petrol as its fuel which undergoes combustion releasing energy and certain byproducts in the form of gases. These gases consist of carbon dioxide (CO2), and carbon monoxide (CO) which are harmful to the environment as they deplete the ozone layer and may interfere with ozone recovery [2]. This in effect, has caused the mean global temperature to steadily increase in the past 40 years as reported by the National Centers for Environmental Information

[3]. As an impact, this has caused the melting of ice caps, which directly causes the rise of sea levels.

In wake of the global climate change, EVs are seen as a better alternative since the vehicles themselves barely produce any harmful emissions. EVs are also seen as an introduction to clean energy into society throughout the global scale.

1.2 Problem Statement

The transportation sector is one of the highest if not the most impactful contributors of carbon dioxide (CO_2) emissions globally. Recent studies by the Intergovernmental Panel on Climate Change, IPCC has proven that the transportation sector is responsible for at least 23% of CO_2 emissions globally, [4] and a high 28% of CO_2 emissions in Malaysia. According to the United States Environmental Protection Agency an approximate 1 gallon (3.785 liters) of petrol produces around 8,887 grams of CO_2 and an approximate 10,180 grams of CO_2 from the same amount of diesel [5]. This can be further assessed by looking at a report from 2019 by S. Khalili et. Al, which states that the total amount of CO_2 emissions in 2015 from the transportation sector is around 8260 Megatonnes [6]. Furthermore, with current rise in CO_2 emissions globally, it does not seem like it will dwindle down any time soon, especially if we take a look at the number of new registered vehicles for the past 5 years [7], which are an approximate value of 4,034,364 vehicles which include both passenger and commercial vehicles. In lieu of using vehicles with internal combustion engines, electric vehicles (EVs) is a better alternative to combat global carbon emissions from the perspective of private and public owned vehicles, since the vehicles themselves produce little to no harmful emissions when they are used on the road. This study will further expand on the demand and potential of EVs especially in Malaysia, in wake of the global climate change.

1.3 Objectives

The main objectives of this study are first, to research and analyze the demand of electric vehicles globally as well as to study the main reasons for current electric vehicle acceptance and adoption of electric vehicles into societey.

Next, this study will further compare the statistical data obtained from this study with other similar simulated data from multiple external sources, notably from the International Energy Agency (IEA).

CHAPTER 2

LITERATURE REVIEW

2.1 Electric Vehicles

Similar to their internal combustion engine counterparts, electric vehicles or EVs for short are widely used in transportation nowadays, in both commercial and personal vehicles. The main and somewhat major key difference between them are that normal cars are powered by an internal combustion engine whereby EVs are usually powered fully by electricity which comes from a battery, or sometimes a hybrid combination of both battery and internal combustion engines. This study will further expand the nomenclature and categorization of the multiple types of EVs that are available to consumers worldwide.

2.1.1 Battery Electric Vehicles

All-electric vehicles or BEVs (also known as pure electric vehicles) are the flagship of EV technology. Using an array of dual or sometimes even four motors, these vehicles are powered by an internal battery cell. Having no engine like normal vehicles, they are powered by high-power, high-density onboard batteries [5]. The most well-known BEV company and manufacturer in the world currently, Tesla, boasts a commendable lineup of 4 models which are the Model S, Model 3, Model X and Model Y. Their battery capacity ranging from 50 to 100 kWh are more than capable to run their vehicles for more than 300 kilometres on a single charge [6]. BEV batteries are fully rechargeable, meaning someone can plug in their vehicle into a power outlet in their house and it will slowly recharge the batteries, or they can opt to charge their vehicles at so called charging stations that are available at their immediate disposal. Honorable mentions of the BEV line are from car manufacturers such as the Honda E from the Honda Motor Company, the Mini E from MINI, Nissan LEAF from Nissan, and the BMW i3 from renowned automobile company, Bayerische Motoren Werke AG.

2.1.2 Hybrid Electric Vehicles

Hybrid electric vehicles are essentially normal cars, wherein they have an internal combustion engine powering the car but simultaenously integrate an electric system in their powertrain. This include (and are not limited to), a small motor attached to the wheels or the drive shaft [8]. HEVs usually have an integrated electronic system within its powertrain. The system controls when and where the motor will be used in place of the engine or sometimes they both work in tandem. For a more detailed example, the hybrid system will use the motor to move the vehicle at low speeds ranging from 10 to 40 km/h, instead of the engine. This system is in place for the purpose of saving fuel, since the engine will only power the acceleration of the car at higher speeds. Another common feature among HEVs are that they have a system which recuperates energy into battery power called regenerative braking. Regenerarive braking works by recovering energy from braking [9], when the brake pads are activated, it will increase the friction between the brake pads and the wheels creating a flux of kinetic energy. This kinetic energy is then harvested by the motor, functioning as a type of generator. The accumulated energy is then restored as electrical charge in the built-in battery. Commonly known HEVs that are commercially available are the Toyota Corolla Hybrid and Toyota Yaris Hybrid from Toyota, Honda City Hybrid from Honda, as well as Volkswagen Jetta from the company of the same name, Volkswagen.

2.1.3 Plug-In Hybrid Electric Vehicles

Plug-In Hybrid Electric Vehicles or PHEVs for short is closely similar to both BEVs and HEVs. PHEVs still boasts an internal combustion engine as its primary powertrain but at the same time it has the features of an HEV such as integrated motors abe plugged in (as its namesake) into a power outlet, similar to how BEVs operate. However, PHEVs cannot be used solely relying on the electrical motors and built-in batteries because they are not that big as an BEV battery. [8] PHEVs are essentially the combination between both BEVs and HEVs taking the great parts of both into one vehicle while still maintaining the traditional internal combustion engine as its main powertrain

2.2 Advantages and Disadvantages of Electric Vehicles

2.2.1 Advantages

The main advantage of an EV over a traditional ICE vehicle is that they do not produce any harmful byproducts, namely carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), and unburnt hydrocarbons (uHCs) [10]. The only byproduct from the operation of an electric car is in the form of heat, primarily from the batteries and motors itself. In accordance to Intergovernemntal Panel for Climate Change, IPCC report section 8: Transport [4], EVs are the way forward in order to combat increasing CO_2 emissions globally. Also mentioned in a previous research, EVs has the potential to emit fuel-production emissions when using low-carbon electricity generation [11].

Since EVs run on electrical power, it does not need the regular maintenance needed which are primarily associated with an ICE vehicle. Said maintenance can range from engine oil replacement, coolant fluid exchange, spark plug replacement, transfer fluid, and etc [12]. Cumulatively, all these maintenance costs could incur quite a hefty financial expense, and this is required annually if a person expects their vehicle to perform at mint condition year after year. EVs does not require as much of the similar maintenance since they do not have an ICE at all. In fact EVs are projected to be more efficient than ICE vehicles, which for 120 years has only had an efficiency of around 30% [13].

Another advantage of electric vehicles is that owners do not need to refuel their vehicles, in the general sense. However, this only strictly applies to EVs and does not include HEVs and PHEVs. Having the luxury of plugging in their vehicles at the comfort of their own home is not a privilege everyone can afford. This saves a lot of time since EV owners do not need to go the a petrol station to refuel. At the same time, EV owners are also comforted by the knowledge that they are no longer affected by the fluctuating fuel prices especially in countries with political instability [14]. Individuals who live in countries that have more access to renewable and clean energy can benefit more to owning and EV since electrical bills are relatively cheap and they do not have to worry to contributing to the global carbon emissions [15].

2.2.2 Disadvantages

There are several disadvantages which are commonly associated with EVs. The major one being that, EVs have a limited range of travel in comparison to ICE vehicles. This is due to the fact that all batteries have a maximum amount of charge that it can store. Also with only 227 public charging locations throughout all of Malaysia [16], it’s not very accessible for everyone to own an EV. This number pales in comparison when we take a look at data provided by the Malaysian Open Data Portal [17] which shows that there are at least 3600 petrol stations countrywide and they are only increasing day by day.

Next, though this might not be well known, EVs generally cost more, both in terms of the financial expenses needed to manufacture an EV as well as its reflected increase in manufacturer standard retail price, MSRP towards consumers. This is due to the fact that sourcing sustainable and carbon neutral materials are relatively hard therefore, are costly, based on a study posted by Financial Times [18]. Also according to the same study, the price gap between an EV and a normal vehicle is an increase of approximately 10%. However, when the world has fully integrated the infrastructure adopting EVs, the prices will eventually go down but for now, they are proven to be higher than their ICE counterparts [19].

The final disadvantage of an EV is that the manufacturing of an EV currently produces more emissions than their ICE counterparts. This is due from the high energy demand required in the manufacturing of large Lithium-ion batteries [20]. However so, similar to manufacturing costs, this will likely decrease in years to come when the technology and infrastructure to manufacture EVs has matured and grown.

2.3 Global Carbon Emissions and Global Warming

Since the main and major reason that we should opt to increase the usage of EVs as well as upgrade and introduce EV infrastructure is due to concerns regarding global warming caused by the burning of fuels of ICE vehicles, it is imperative that we also take a look at what is global warming in a general sense.

2.3.1 Causes of Global Warming

There are a multitude of factors that contribute to global warming, be it large or small. However there are a few of them which plays a major role in being the causes of global warming for the past few decades. First of which is the burning of fossil fuels, a study estimates that 40% of global CO2 emissions come from Coal alone [21]. As per previously mentioned in a research by R. D. Reitz *et. al.* [10], the burning of fossil fuels produces harmful molecules which are known as greenhouse gases such as CO_2, CO, uHCs, as well as NO_x. Other than that, the burning of other types of fossil fuels such as the burning of coal which releases ash, CO_2, CO, sulphur dioxide (SO_2), NO_x and suspended particulate matter which all contribute to the increase in greenhouse gases [22]. These so called greenhouse gases accumulate around the ozone layer and they trap UV rays that are radiated from the Sun. This phenomena then consecutively causes the global earth temperature to rise.

Next, deforestation of forest reserves worldwide has also caused the steady increase in global temperature [23]. From a study made by Winrock International and Woods Hole Research Center which are based in the US, their findings estimate that deforestration is responsible for at least 10% of global temperature increase [24]. This is due to the fact that trees act as a mediator of the nature, they play an important role in regulating the global climate, as they absorb CO_2 from the atmosphere and releases oxygen back into the atmosphere [25]. If the continual deforestatation is left unregulated by authorities, it will further increase the global temperature in the years to come.

Furthermore, agriculture and farming is also a major contributor to the increasing global temperature worldwide. An estimated 10-12% of current global greenhouse gas can be traced back to livestock as its source [26]. Livestock such as cattle and sheep require vast amounts of land for grazing and feeding. To accommodate this industry, livestock farmers are often left with no choice but to clear out virgin forests and trees to make space for their livestock. This causes a similar effect mentioned previously [25]. At the same time, livestock droppings produce massive amounts of methane gas (CH_4) which is a contributor to the increase in greenhouse gases, and consecutively the rise in global temperature [27]. For the similar reasons as livestock farming, vegetable farmers also face the same problem: they require massive areas of land for the cultivation of their produce which are usually solved by unregulated deforestation.

2.3.2 Effects of Global Warming

Global warming has long since been debated to cause dangerous and long-lasting impacts on our planet. More than 197 international scientific organizations agree that global warming is real and has been caused by non other than ourselves [25]. The most prominent effect of global warming is the melting of ice caps. The melting of ice caps pose a major problem to nations worldwide. Based on a research done by Climate Central, a science organization based in New Jersey, USA, the sea levels will constantly rise to the point that one day, some coastal cities, Malaysia included, might be submerged in water by 2050 if no action is taken to mitigate this problem [26]. This will cause millions of people to lose their homes, and with the loss of kilometres worth of land, some countries might even lose their people to famine.

Furthermore, with less land mass available as well as the increasing number of people in the next 30 years, food security will be a high time problem globally. Based on a study made by the United Nations, the human population is projected to reach around 9.8 billion people in the year 2050 and 11 billion in the year 2100 [27]. Food security will face chaos in the face of several billion people in years to come, if global warming is not taken seriously.

Moreover, the likeliness for extreme weather events to occur such as typhoons, wildfires, heat waves, drought will increase drastically. The increase in global temperature coupled with the steady rise in greenhouse gases has caused the natural weather cycle of the earth to become uncertain and unpredictable based on a report by the IPCC [28]. In the future many lives will be the casualties of these unpredictable weather phenomenon if no action is taken by policymakers and governments worldwide to combat global warming.

2.3.3 Potential Solutions to Combat Global Warming

As of the main topic of debate in this research, the number one solution that should be immediately adopted to combat global warming, is to reduce the burning of fossil fuels. As previously mentioned, more than 40% of global CO2 emissions are contributed by fossil fuels [21]. By building and upgrading existing infrastructure that support EVs, the general population will be less hesitant in the idea of owning an EV. With accessible EV infrastructure such as a wide array of charging stations placed throughout the country, EVs will be compelling for the general population to try, not just the ones living in the center of mega cities.

Following the previous discussion on reducing the usage of fossil fuels, policymakers and governments should opt to utilize alternative sources of clean energy such as wind or tidal power.

2.4 Oil Displacement and CO2 Emission Equivalence

A key term when talking about EVs in general are Oil Displacement and CO2 Emission Equivalence. Oil displacement describes the amount of oil displaced when society opts to use EVs in place of ICE vehicles. CO2 is their subsequent amount of emissions that can be calculated if said fuel is displaced, which means that less CO2 would be released, theoretically.

Oil displacement is generally measured per million litres and CO2 emission equivalence are measured in Megatonnes (Mt). Based on a study done by the IEA[28], by the year 2030, around 125,000 Million litres of gasoline will be displaced when EVs will become the mainstream transportation globally.

2.5 Trends and Developments in Electric Vehicle Markets

After a decade of EV growth in market shares, in 2020, the global electric car stock reached a record high of approximately 10 million units. This marks a 43% increase from the previous year (2019)[29]. Despite the ongoing COVID-19 pandemic, global electric car sales has increase about 70% to 4.6% market share in the year 2020. Around 3 million new electric vehicles were registered with Europe leading the race with 1.4 million new registrations followed by China with 1.2 million registrations. The United States registered around 295 thousand new electric vehicles in the same fiscal year.

Numerous factors can be the reason as to why EV sales were very positive eventhough the world was facing COVID-19; first of which, policy support from EU countries regarding car sales were outstanding. Purchase incentives for EVs were increased, especially in Germany. Furthermore, the declination of costs in battery for these particular EVs are the other reason why EV sales were skyrocketing during COVID-19. Following the second half of global lockdown, where the global economy was starting to recover, EV sales surged tremendously which amounted to 4.6% market share by the end of 2020.

2.6 Main EV Support and Stimulus Policies in 2020

Region/Country	Electric Vehicle Support and Stimulus Policies in 2020
European Union	- CO2 emission standard for cars were standardized to a maximum of 95 g CO2/km starting in 2020. - EUR 750 billion is financed for Next Generation EU and Recovery plan for Europe (37% of the funding is channel towards climate change mitigation).
China	- New Energy Vehicle mandate: This program is focused on subsidizing EV sales in China.
United States	- Corporate Average Fuel Economy Standard is implemented; which is around 38.5 miles per gallon in the year 2020. - A maximum number of federal purchase tax credit was increased up to USD 7500 for BEVs.
France	- A purchase subsidy of EUR 6000 is offered for cars emitting 20 g CO2/km - Charging Infrastructure deployment targets 100,000 public chargers to be built by the end of 2022. - Maximum BEV purchase subsidy was increased to EUR 7000. - Additional new PHEV purchase subsidy is offered around EUR 2000.
Italy	- A purchase subsidy of EUR 4000 – 6000 for cars emitting less than 20 g CO2/km and EUR 1500 – 2500 for cars emitting 21 – 60 g CO2/km. - An additional EUR 2000 purchase subsidy for cars emitting 2 g CO2/km.
Germany	- Purchase subsidy of EUR 6000 for BEVs and EUR 4500 for PHEVs. - All petrol stations are compulsory to provide charging stations for EVs. - No more subsidies are offered for conventional vehicles.
United Kingdom	- A maximum purchase subsidy of GBP 3500 is offered for BEVs and PHEVs with 2 g CO2/km with range conditions. - The scheme is extended up until the year 2030.

Table 2.1: Main EV Support and Stimulus Policies in 2020.

CHAPTER 3

METHODOLOGY

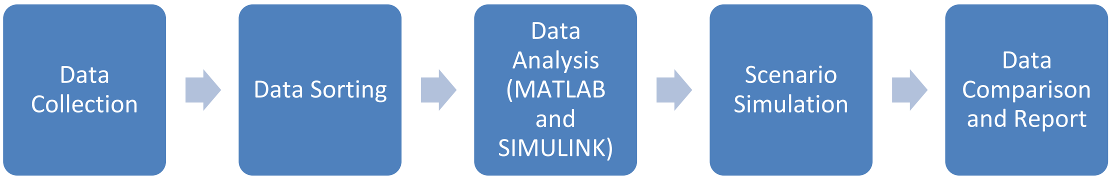

Figure 3: Procedural Flow Chart

3.1 Data Collection

The data was sourced from the official International Energy Association website[30]. These data were selected for this study because they represent the most accurate data regarding electric vehicles from multiple sources and publications worldwide, The Global EV Outlook is an annual publication made by the International Energy Agency that discusses the electric mobility across the globe. Their study is developed in support from the members of the Electric Vehicles Inititative. Using historical analysis, the publication made by the IEA, have projected key figures that involve the electric vehicle’s area of interest, which include but are not limited to EV stock, sales, energy use, CO_2 emissions and battery demand.

Therefore, for this study specifically, all the data for global EV car stock and sales can be obtained. The data is further downloaded onto an excel spreadsheet.

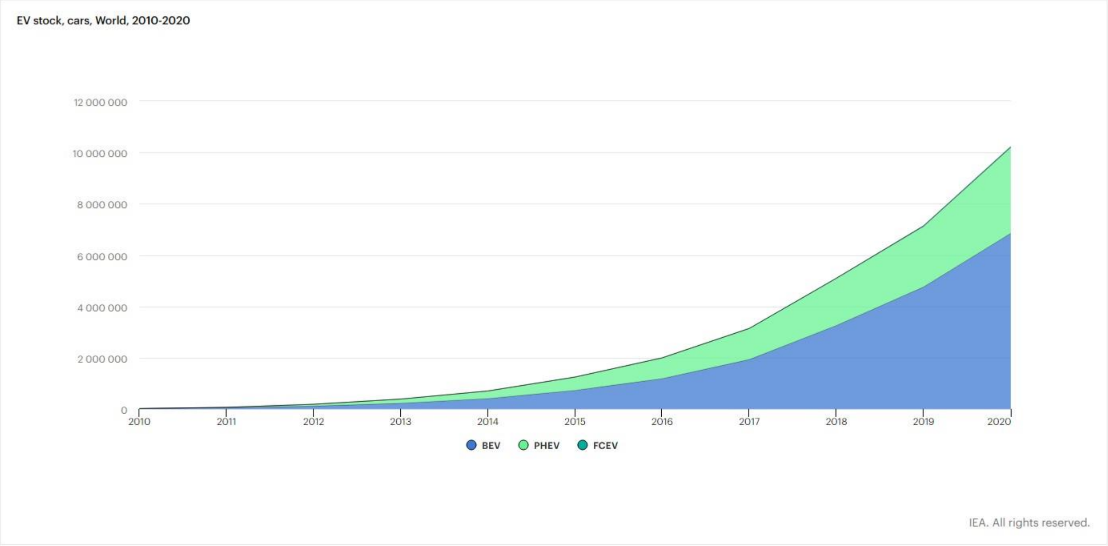

Figure 3.1: EV Stock from the year 2010 to 2020.

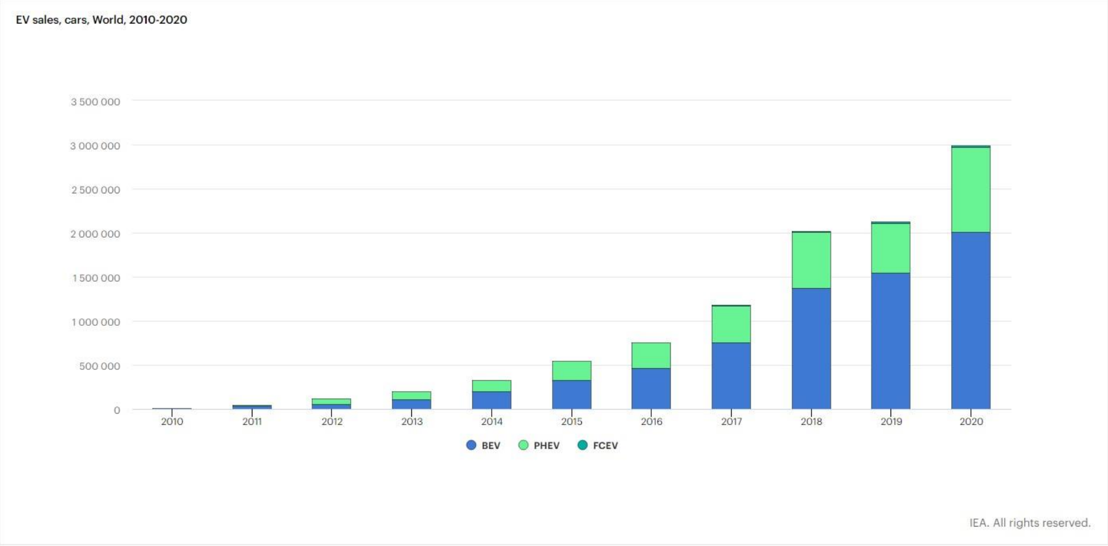

Figure 3.2: EV Sales from the year 2010 to 2020.

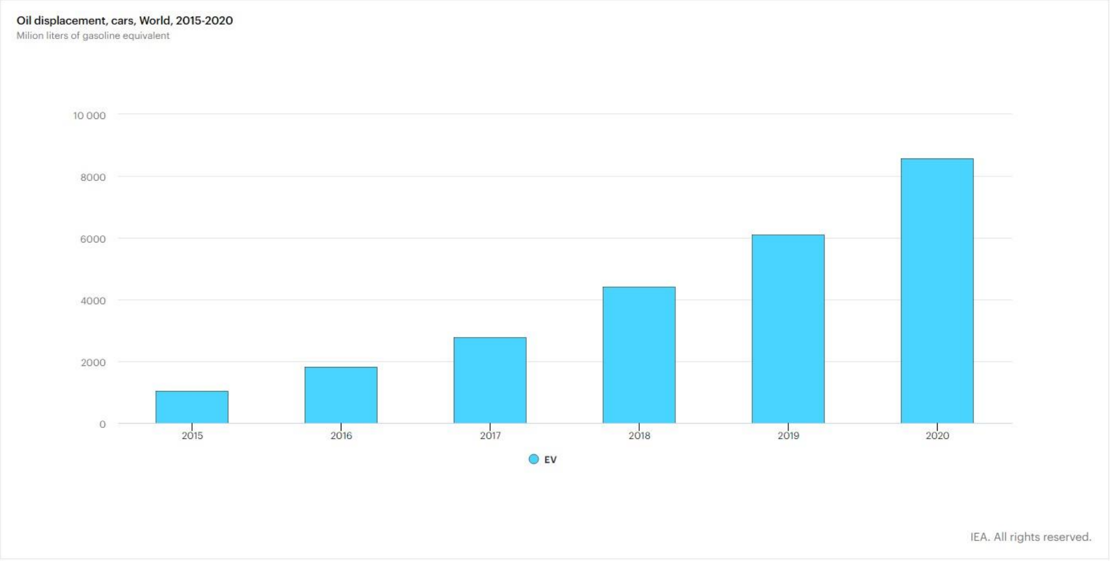

Figure 3.3: Oil Displacement from the year 2010 to 2020.

3.2 Data Sorting

After importing data from the IEA website, the data was sorted and separated acoording to EV Stock, EV Sales, and Oil Displacement according to their respective years and countries. Since this study intends to determine an overall data analysis, this study will only be taking into account the data from the global section, since it has already accounted for all worldwide EV stock, Sales and Oil Displacement.

3.3 Data Analysis through MATLAB and Simulink

From the previously sorted spreadsheet, the data will be saved and imported as a file into MATLAB for further analysis. Afterwards, a callback sequence will be utilized to obtain the subsequent data and input it into Simulink through the 'Lookup' Block command.

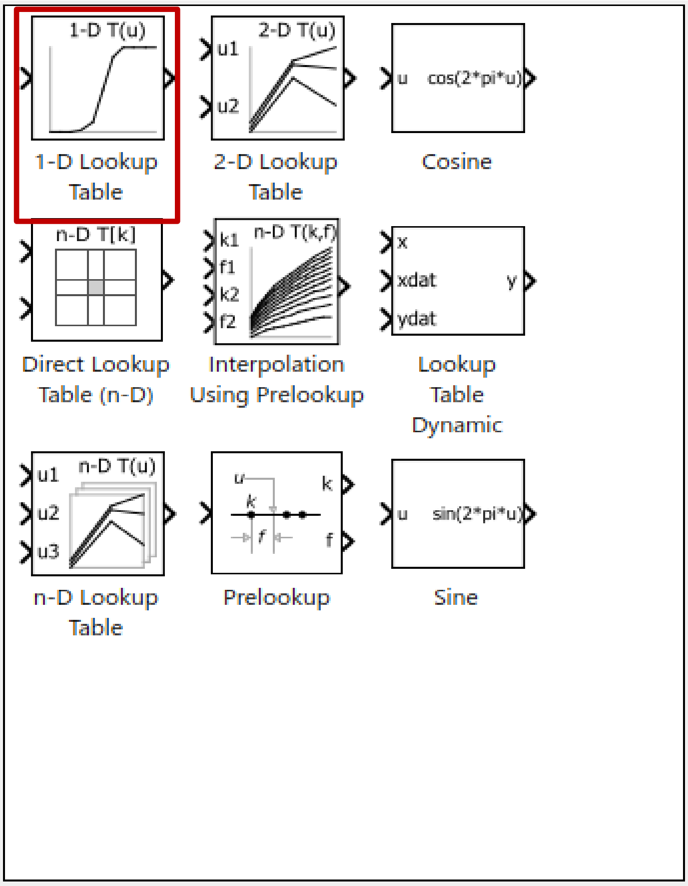

Figure 3.4: Lookup Table block command in Simulink.

Since the imported data is only a fixed integer against Year, the data will utilize the 1-D Lookup Table for further simulation. Inputing the year and the respecting parameter, such as EV Stock or Sales, the subsequent data for EV stock and sales for a specific year can be obtained in real time.

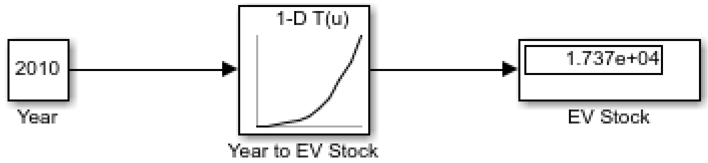

Figure 3.5: Block Diagram for EV Stock Simulation.

As shown in the block diagram above, when the input data is the year 2010, the output data will obtain the exact figure for EV stock in that particular year. The same applies for any other particular year up until 2020. This shows that the command model is accurate in representing input and its output data for our paramters, which are EV stock.

A same block diagram can be made for Oil displacement vs Year, however in this block diagram, an additional output command is added that converts oil displacement (Million litres) to its CO2 emission equivalence in Megatonnes.

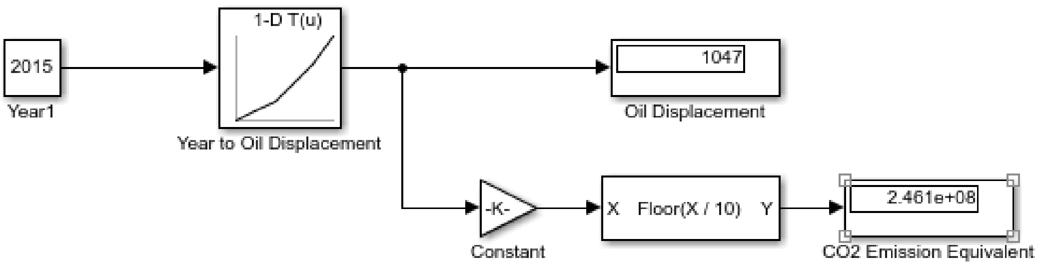

Figure 3.6: Block Diagram for Oil Displacement vs Year.

3.4 Scenario Simulation

In scenario simulation, different scenarios will be assumed and input it into the model to see the future outcome of the model. In a way this will provide the study with a projected data for EV stock and sales, as well as oil displacement and their CO2 emission equivalence for upcoming years. The scenarios that this study will be using are as follows;

3.4.1 Increase in EV stock and sales by 20% from the year 2020 up until 2030

Using a fixed growth factor of 20%, this study will simulate or forecast the stock and sales from the year 2020 through 2030. In terms of EV growth globally, China is a good example that can be used to demonstrate the prediction model since they represent the largest car market worldwide. Since China has shown a relatively constant growth of EV inventory since the year 2005 which closely appropriates 20% annual growth factor, this study will also model this scenario with a growth factor of 20% [31]. Therefore, similar with the previous block diagrams used to obtain the EV stock/sales from a particular year, this scenario will require the future projection year, next the simulation model will have the ‘Gain’ block after the lookup block to simulate that it has an increase in stock/sales. By doing these steps, the study will obtain a projection value of 20% based off of the data that have been input into the lookup block earlier.

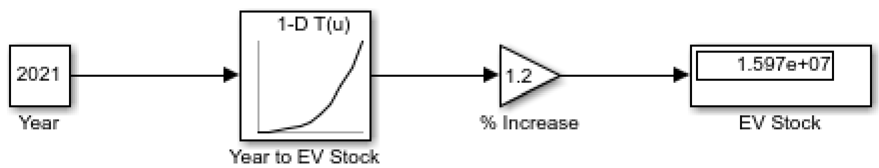

Figure 3.7: Block Diagram for Projection Simulation with 20% Linear Growth.

From the block diagram shown above, the data that have been input a models a 20% increase of EV stock from the previous trendlines, and obtained an output of 15.9

million EV stock for the year 2021. The same value for EV sales can be obtained using the same block diagram.

3.4.2 Increase in EV stock and sales by 20% every year from the year 2020 up until 2030

Furthermore, the study is continued with the second scenario by assuming that in the upcoming years, the EV stock and sales will increase by 20% every year based from the trendlines from 10 years ago which was provided by the IEA. This assumes compound annual growth of at least 20 – 30% from the year 2020, as reported by the IEA in their findings. From this data, an expected data can be simulated for exponential growth of both EV stock and sales.

3.4.3 Oil Displacement and CO2 emission equivalence projection

Next, using the data that have been imported regarding oil displacement, this study can also construct a projection graph to simulate the oil displacement and CO2 emission equivalence for the upcoming years 2021 through 2030. An important aspect to why oil displacement and CO2 emission equivalence is used as a simulation parameter in this study is due to the fact that, long term emissions of CO2 will heavily impact the sustainability implications of the predicted EV market growth [31], and it has been proven in one study that EVs may provide long-term environmental benefits, such as the gradual decrease of greenhouse gases [32].

CHAPTER 4

RESULTS AND DISCUSSION

The results are categorized into two key parts, the first one being, Scenario 1; which is assumed that the growth of EV stock and sales from the year 2020 through the year 2030 is a linear growth of 20% based on the study done by N. Rietmann (2020) as stated in section 3.4.2 of this study. The second one, Scenario 2; is assumed that the growth of EV stock and sales from the year 2020 through the year 2030 is an exponential growth of 20% which is based upon the trendlines predicted by the IEA. Afterwards, from the projected data values, this study converts the values and obtains their subsequent oil displacement equivalence and CO2 emissions equivalence for both scenarios respectively.

4.1 Scenario 1: EV Stock and Sales with 20% growth from 2020 to 2030 (Linear Growth)

After inputing the projected value of 20% growth into our block diagram, these are the figures that we have obtained for EV stock and sales from the year 2020 through the year 2030.

Projected EV stock (20% growth)	
Year	Total EV Stock (Millions)
2021	15.97
2022	19.67
2023	23.37
2024	27.07
2025	30.77
2026	34.47
2027	38.17
2028	41.87
2029	45.57
2030	49.26

Table 4.1: Table of Projected EV Stock with 20% Linear Growth.

Projected EV sales (20% growth)	
Year	Total EV Sales (Millions)
2021	4.62
2022	5.66
2023	6.69
2024	7.73
2025	8.76
2026	9.80
2027	10.83
2028	11.87
2029	12.90
2030	13.94

Table 4.2: Table of Projected EV Sales with 20% Linear Growth.

Projected data of 20% growth gives us a linear graph from 2020 through 2030 for both EV Stock and Sales.

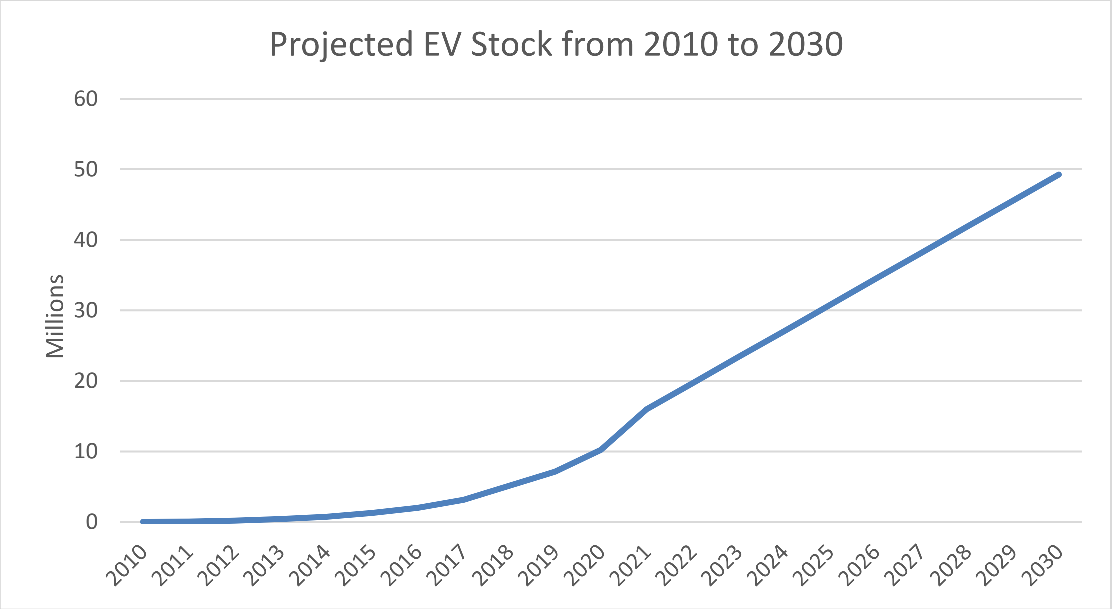

Figure 4.1: Graph of Projected EV Stock from 2010 to 2030.

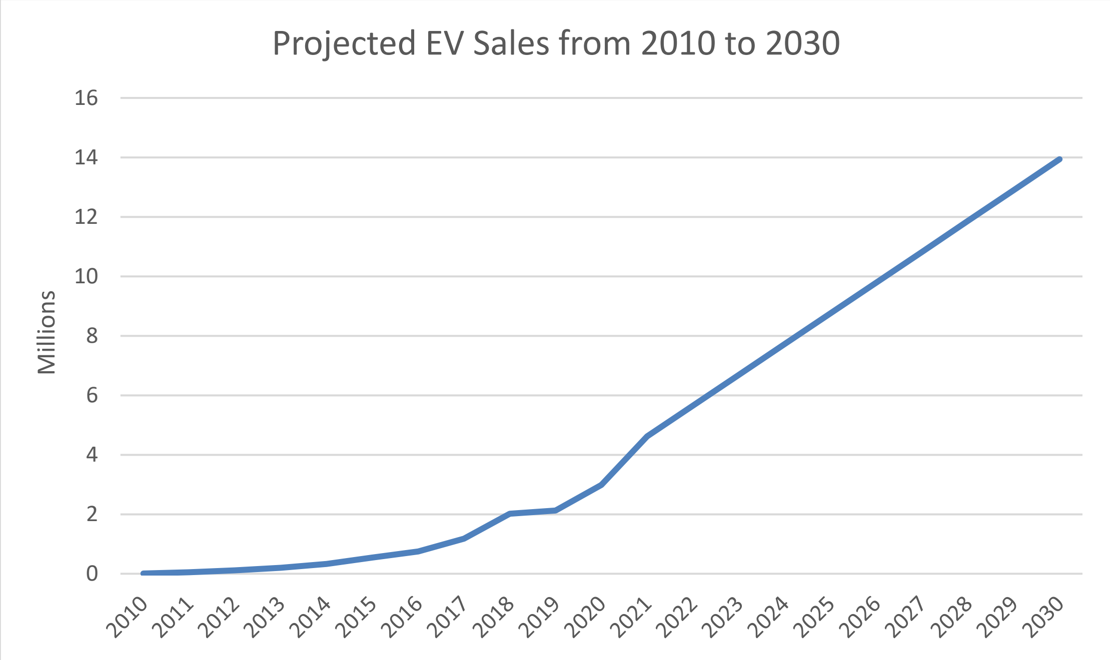

Figure 4.2: Graph of Projected EV Sales from 2010 to 2030.

4.2 Scenario 2: EV Stock and Sales with 20% growth every year from 2020 to 2030 (Exponential Growth)

After inputing our projected value of 20% growth every year into our block diagram, these are the figures that we have obtained for EV stock and sales fryear 2020 through the year 2030

Projected EV stock (20% growth annually)	
Year	Total EV Stock (Million)
2021	12.27
2022	14.73
2023	17.67
2024	21.21
2025	25.45
2026	30.54
2027	36.65
2028	43.98
2029	52.78
2030	63.33

Table 4.3: Projected EV Stock for 20% Annual Growth.

Projected EV sales (20% growth annually)	
Year	Total EV Sales (Millions)
2021	3.58
2022	4.30
2023	5.16
2024	6.19
2025	7.43
2026	8.92
2027	10.70
2028	12.84
2029	15.41
2030	18.49

Table 4.4: Projected EV Sales for 20% Annual Growth.

Projected data of 20% growth gives us an exponential graph from 2020 through 2030 for both EV Stock and Sales.

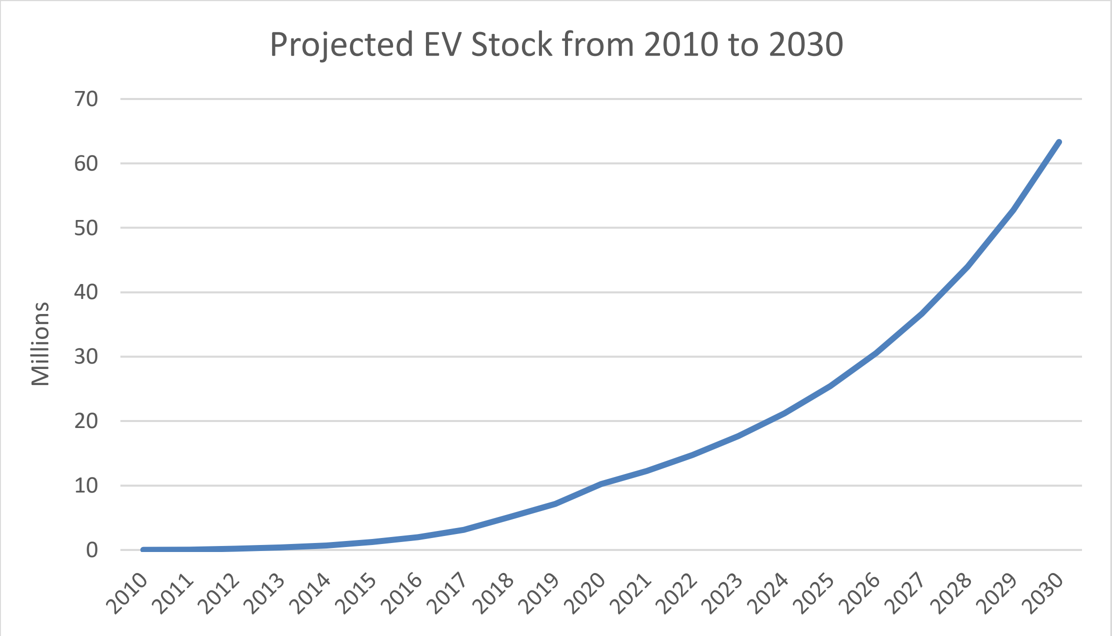

Figure 4.3: Graph of Projected EV Stock from 2010 to 2030 (20% Annual Growth).

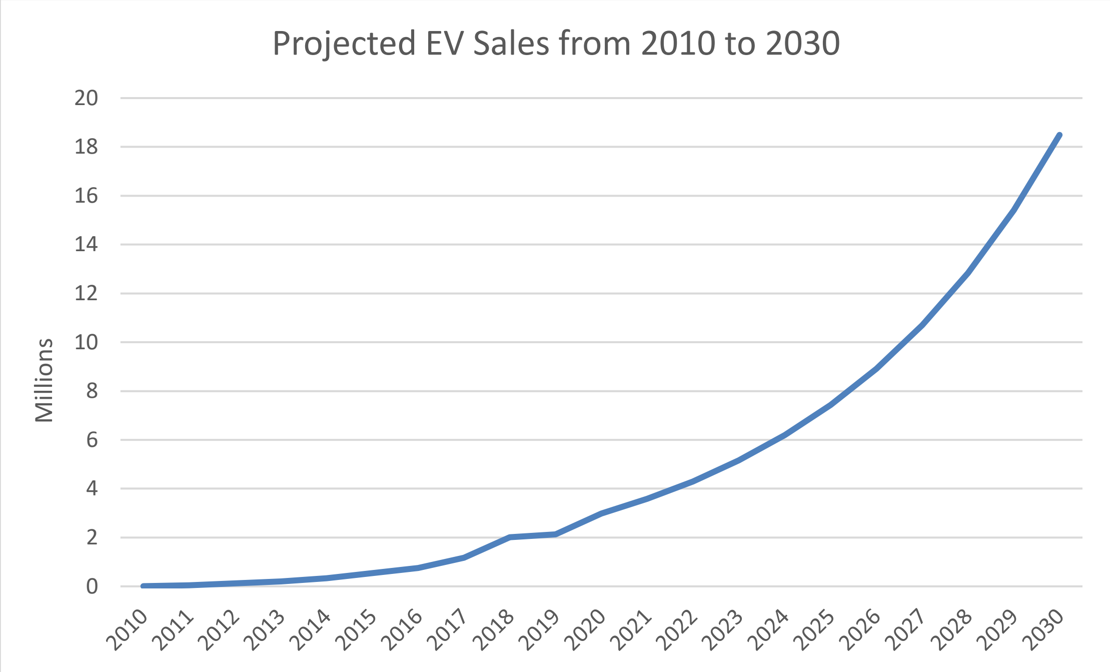

Figure 4.4: Graph of Projected EV Sales from 2010 to 2030 (20% Annual Growth).

4.3 Projected Oil Displacement and CO2 emission equivalences

Continuing on with the same block diagram from Simulink, the future oil displacement and CO2 emission equavalents of the growing EV market both in linear and exponential terms is predicted. Using a simple formula, this study will convert the oil displacement into their respective CO2 emission equivalence. From the Deparment of Natural Resources Canada, it has been found that approximately 1 liter of petrol will produce around 2.35 kg of CO2 after combustion. The formulae is as follows;

$$CO2\ Emission\ Equivalence\ (Mt) = \ Oil\ Displacement\ (Liter) \cdot 2.35\ kg/L \quad (4.1)$$

Using this formulae , the subsequent CO2 emission equivalence can be calculated from the year 2021 all the way to 2030. However since the CO2 emission equivalence in this study is empirical in question, the data is inversely translated into a negative integer to show the negative CO2 emission.