THE EFFECT OF GOVERNMENT POLICY ON THE BATTERY ELECTRIC VEHICLE DEMAND

BY

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ABSTRACT

The electric vehicle trend is rising high around the world. Many people have selected battery electric vehicles (BEVs) as their first choice, but Thailand did not get that much attention. In 2020, BEVs took around 54.3% of the first car market increase from 2019 by 11.9% (Norway first country to see electric cars comprise 50% of net vehicle sales, 2022). So, this study examines any factors that impact BEVs and their impact on each factor. This study aims to develop a system dynamics model to forecast the effect of Thai government policy on BEVs and use this model to conduct the policy analysis to increase battery electric vehicle users in Thailand. The purpose of this study is to examine the effect of Thai government policy on electric vehicle demand in Thailand. To analyze the scenarios of which policies should be lunch together and suitable for Thai government situations. The main procedure for forecasting the trend of electric vehicles includes gathering data sources, validating key factors, and system dynamics modeling approach to model the trend of BEVs usage. Furthermore, the sensitivity analysis of three key factors was also conducted.

Keywords: Battery electric vehicles, System dynamic modeling, Key factors, Government policies, Thailand

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Symbols/Abbreviations	**Terms**
EV	Electric vehicle
AEV	All-electric vehicle
PHEV	Plug-in hybrid electric vehicle
BEV	Battery electric vehicle
SD	System dynamic
CO_2	Carbon dioxide

CHAPTER 1
INTRODUCTION

In recent years, the transportation industry has become one of the humans' essential activities because there are many places to visit every day. These activities will cause an increase in the emission of carbon dioxide in the road transportation sector. Emissions from energy consumption in the road transport sector accounted for 11.9% of the total global emissions in 2020, the most emission from all sectors (Ritchie, 2020). Furthermore, road transportation causes a carbon dioxide emission problem. It causes a PM2.5 problem that makes humans more concerned about their health, and both problems mainly occur in cities with heavy traffic jams.

There are many alternatives for road transportation activities in Thailand, and the electric vehicles (EVs) is an alternative. Public transport vehicles, private vehicles, and motorcycles are common alternatives in Thailand for road transportation. The government has implemented some policies about alternative energy use in transport which introduced EVs to the Thai market. EVs use electricity as the energy source to impel, reducing carbon dioxide emissions, reducing PM2.5, and global warming. The EVs can be classified into two primary types all-electric vehicles (AEVs) and plug-in hybrid electric vehicles (PHEVs)(ENERGY, 2021). This paper studies one of the AEVs types, battery electric vehicles (BEVs), that have zero-emission for the concept of this technology. Using BEVs for transport and travel is one of the most effective ways to solve the fuel economy, energy consumption, and environmental problem in the long term. However, there is a significant barrier to stimulating people to buy BEVs because of price, social economy, and the government support policy (Xiang, 2017).

1.1 Problem Statement

One of the most critical barriers that are unavoidable for using BEVs is the support policies from the Thai government. Therefore, the government subsidies and support tax policy can impact intensive to increase the attention from Thai market to increase the demand for BEVs (Li et al., 2018).

From the Thai government policy, this research looks for the effect of government policies on demand for BEVs that increase dynamically, and the value of demand is changing over time with the influence from significant factors. A system dynamics modeling is an effective tool to solve the large and complex engineering problem to capture the interaction between each factor. A system dynamics modeling is concisely chosen to handle an increase in a dynamic form of demand in government policies.

1.2 Research Objective

1. To examine the effect of Thai government’s policy on battery electric vehicle (BEVs) demand in Thailand.
2. To develop the system dynamic model to forecast the number of BEVs in Thailand.
3. To find the different combination of the policies and see the possibility to adopt with Thailand situation.

This research aims to develop a system dynamics (SD) model to forecast demand for BEVs in Thailand. Each government policies factor's relationship is implemented in the model to determine any connections among the factors. Sensitivity analysis will help validate the model's sensitivity to be allowed in future use.

CHAPTER 2
REVIEW OF LITERATURES

2.1 Global Warming

Global transportation is a significant consumer of world oil output and a leading source of greenhouse gas emissions from carbon dioxide (Patrick Moriarty, 2017). The greenhouse gas emission can last for years in the atmosphere, resulting in climate change worldwide, for example, heatwaves and heavier rainfall. The impacts of climate change are dangerous to every person. Many countries affected by heatwaves result in thousands of deaths. Snowmelt causes flooding and rising sea level. Rising sea levels will lead to more coastal areas being flooded and damage to the household and agriculture for many years. The change in the daily habits of humans can reduce global warming. There are many alternatives to reduce CO2 emissions and mitigate climate change through the widespread adoption of all-BEVs (Bo MacInnis, 2020).

2.2 Government Policy

The governments of many countries have been promoting the development campaign for BEVs. For example, governments of some European countries have launched campaigns to promote BEVs by creating the incentive for people to buy new BEVs, and these policies cover many aspects such as manufacture, purchase, use, and charging (Wang et al., 2017) and so on. In practice, governments of several countries introduce some imported BEVs with superior comprehensive performance into domestic markets. The policy can result in a trade-off between BEVs price and subsidies on the optimal production decision of BEVs. Show that the support from the government can increase the production quantity of BEVs and demand uncertainty with the study of government subsidies.

This study studies only in Thailand, and this study is to simulate the potential policy that has already been implemented with existing policy in Thailand. For example, the first car policy is conducted for combustion cars in 2011, this policy has the potential to apply this same model to the BEVs policy and create a different scenario of existing policy and potential policy. At the moment annual tax policy and import tax policy is announced by the Thai government. If governments applied the first policy what happens if government policy what happened. My study is looking for the different scenario of the policy and seeing which one is the best suited.

The tariff policy is needed to be considered for the domestic BEVs market (Fan et al., 2020). The impact of introducing imported BEVs on the domestic market is that domestic manufacturers can produce more high-quality products and bring more social welfare when the quality is high. This impact indicates that implementing the subsidy and tariff policies can help increase the production quantity of domestic BEVs and their market share. Also, the production quantity of domestic BEVs depends on the relationship between the total cost of producing BEVs and the degree of technology spillover.

First, this study defined that the size of BEVs is divided into two categories. The small car category is the BEVs that weight is below 1750KG, and the medium-large car category is the BEVs the weight is higher than 1750KG. These two categories are defined according to the weight of combustion engine cars compare to engine sizes.

2.3 First Car Policy

Thai government begin impelling the first cars policy to increase the BEVs, but the first cars policy is for the BEVs company. So, the first car policy needs to apply to the policy tax reduction in the forecast model for five years. In 2011, the policy was released, and the amount of cars is rising high. Due to this policy, it may make the BEVs trend increase the same as 2011. demand uncertainty with the study of government subsidies.

The concept of the first car policy is the individual to buy a small category car and get a tax refund of up to a maximum of 100,000 baht. A car with an engine of no more than 1.5 liters is defined as a small category car (Transport Statistics Sub-Division, 2022). Those eligible for the first car policy are Thais who had never owned vehicles before and must own the vehicles for at least five years. Also, a condition for cars in which the price is no more than 1 million baht. From data collection, the number of combustion cars from the first car policy in the first two years resulting in an increasing rate is 12.96%. After the first two years, the increase rate drops to 10.8% (Transport Statistics Sub-Division, 2022). The medium-large car category is not effect in this policy.

The first cars policy guideline is to refund tax to a consumer only on the first car purchased. In other words, the condition of the first cars policy is that consumers must never purchase a car before. The cars that involve in the policy must be below 1500cc. In addition, the tax will be refunded one year after purchasing the car. The refund tax will directly transfer to the bank account of the consumer.

2.4 Annual Tax Policy

The taxation of gasoline is characterized by large variability across countries and recent research has analyzed existing gasoline tax levels from an economic efficiency point of view focusing on conventional internal combustion engine vehicles. (Tscharaktschiew, 2015) From the study of Consumer preferences for BEVs: a literature review (Fanchao Liao, 2017) identified that the impact of the financial attributes of BEVs is significant, including its annual tax.

The concept of the annual tax policy is to use the small car category and the medium-large car category. (Transport Statistics Sub-Division, 2022). An annual tax policy will develop every year until 2036, the first five years is calculated by the weight of BEVs. In year 6, it will receive an annual tax reduction of 10 percent.

The tax reduction rate top up by 10% each year, year ten and subsequent years tax reduction rate is 50%.The amount of saved money from the average of taxes reduction for both small BEVs category and medium-large category. Then the amount of saved money from annual taxes will be divided by average car prices and the result is getting the total increase in BEVs for both categories.

The study of Analysis of the Electric Vehicles Adoption over the United States (Ali Soltani-Sobh, 2016) shows that the gasoline price and electricity prices affect BEVs adoption. If the electric price decreases, BEV adoption will increase. This can be a reference to when the annual tax of BEVs decrease, the cost for BEVs owner will keep decreasing. This policy used datasets to compare the cost of annual tax for BEVs and the cost of annual tax for a combustion engine. The method is that the annual tax on BEVs cost is cheaper than the annual tax on combustion engines in long-term usage. So, this factor may increase more BEVs in Thailand.

2.5 Import Tax Policy

Mass adoption of BEVs is anticipated in the years ahead, driven primarily by policy incentives, rising incomes, and technological advancements. (Ben Jones, 2020) Thailand is facing the global warming problem, and the main reason comes from the transportation that produces carbon dioxide emissions. Because of this pain point, the governments will support BEVs consumers to reduce carbon dioxide emissions. The barrier prevents the Thailand BEVs as consumers are concerned about the high price of BEVs because of import taxes and the limitation of charging stations in Thailand.

The concept of the import tax policy is to use the small car category and the medium-large car category. (Transport Statistics Sub-Division, 2022). An import tax policy will develop for five years, first two year is calculated by the import duty tax reduce up to 40%. After two years, the import excise tax at 8% will reduce to 2%.

The amount of saved money from the average of taxes reduction for both small BEVs category and medium-large category. Then the amount of saved money from annual taxes will be divided by average car prices and the result is getting the total increase in BEVs for both categories.

Thai government is currently producing a campaign about reduced import tax for BEVs. Governments want to restructure the import tax infrastructure so consumers can easily access flexible BEVs prices. Because high sticker prices restrict BEV sales, governments offer consumers BEV subsidies. (Seiki Tanaka, 2022) Shortly, when BEVs price decreases, Thailand citizens will start using BEVs because of the profits consumers can gain from the prices and the effect on the environment in the country.

2.6 System Dynamic Modeling

Today, most automotive industries use system dynamics modeling to forecast trends, pollution, economy, ETC. This study's forecast model uses system dynamics modeling as the central part. Their research study about the relationship between EVs demand, charging stations, and EVs attractiveness to find the relationship between these three primary factors (Xiang et al., 2017).

Another research that uses system dynamics modeling was the study that uses SD modeling to research the relationship between car price, Market demand, and supply to the impact and sustainability in the automotive industry (Barazandeh & Rafieisakhaei, 2017).

SD model objective is looking for feedback loops, analyzing the trend and relationship between each factor, and then using this information to create a new strategy. This research examined the automotive study of fast charging infrastructure trend using system dynamic modeling to analyze the factor from previous research in other countries and adapt the research to use in Thailand.

CHAPTER 3
RESEARCH METHODOLOGY

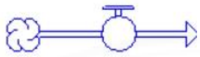
This research aims to develop a system dynamics model of BEV sales from Thai government policy campaigns. This research approach is carried out in five stages, including 1.) Literature review of government policies affecting BEV sales 2.) Model development 3.) Simulation results 4.) Model validation 5.) Conclusion.

In the first stage, a literature review was conducted to identify three key factors that affect BEV sales, starting from gathering valid information and listing the factors that have affected the number of BEV sales. The second stage includes model development that contains affected variables inside the number of BEV sales. The third stage is developing a model which got a simulation result that causes the model to examine the forecast number of BEV sales. The next stage is model validation by using sensitivity analysis for different scenarios to achieve the recommendation for action in the future. Finally, it summarized all the detail and concluded the model results. The development of BEVs is one of the most effective ways of solving energy and environmental problems (Xiang, 2017).

3.1 SD modeling

System dynamic (SD) is a robust methodology that aims to develop a computer simulation model to analyze complex issues and problems. SD model can also solve large-scale engineering issues and problems (Azar, 2012). SD deals with the interaction between the various relationship of each factor, inputting each factor into the element of the model and connecting them. By capturing the dynamic aspect by incorporating the concept of the elements, thereby providing insight into the systems' dynamic behavior over time (Tang & Vijay, 2001). In addition, with its ability to analyze complicated and dynamically behaving systems, sensitivity analysis can be constructed and performed, allowing users to adjust management on their model. These elements are explained and visualized in the table 3.1:

Table 3.1 Components of system dynamic modeling

Name of element	Icon	Explanation
Stock		Represent a part of a system whose value at any given instant in time depends on the system's past behavior or something that accumulates.
Flows		Flows represent the rate at which the stock is changing at any given instant. They either flow into a stock (causing it to increase) or flow out of stock (causing it to decrease) or activity that changes the magnitude of stock.
Converters		Used to take input data and manipulate or convert that into some output.
Action connector		To transmit inputs and information.

CHAPTER 4
MODEL DEVELOPMENT

This model forecasts the effect of government policies on BEV sales in Thailand by looking at three key factors that impact model development. The first factor that has an impact on the model is the first cars policy.

All policies explored support EV adoption and reduced CO2 emissions independently. (Ledna & Muratori, 2022) The data used to calculate all policies come from the historical data of total cars, total new registered cars, (Transport Statistics Sub -Division, 2022), and total BEVs (Thailand, Electric Vehicles Association of, 2022). First, this study defined that the size of BEVs is divided into two categories. The small BEVs category is the BEVs that weight is below 1750KG, and the medium-large BEVs category is the BEVs the weight is higher than 1750KG. These two categories are defined according to the weight of combustion engine cars compare to engine sizes.

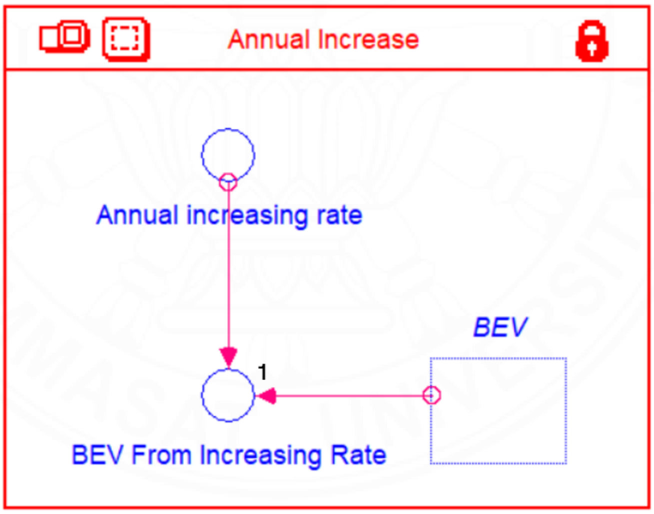


Figure 4.1 Annual Increase.

$$BEV\_From\_Increasing\_Rate = Round(BEV*Annual\_increasing\_rate) \quad [1]$$

To observe that if the first car policy is released for BEVs, how many BEVs can be increased from the first car policy taxes reduction. This factor required the information of different ratios each year using the cumulative BEVs compared with the number of total cars that forecast from its annual increasing rate to increase the ratio of BEVs to total cars [1].

The first cars policy model applied the data and concept from the first car policy in 2011, and the amount of cars is rising high due to tax reduction in the first five years with a high increase rate in the first two years and less in the following three year [2] [3]. The increasing percentage of the first car policy comes from the amount of money saved from the average of taxes reduction for small BEVs category multiplied by the total small BEVs category. Then the result is the total amount of money that can be saved from a tax reduction for small BEVs category. Divide all the saved amount of money by the average car price for small BEVs category, and the result is getting the total increase BEVs, and convert the total increase BEVs into a percentage to apply in the first car policy model. For the small BEVs category, the percentage increase is a different rate but will use the same method as small BEVs category.

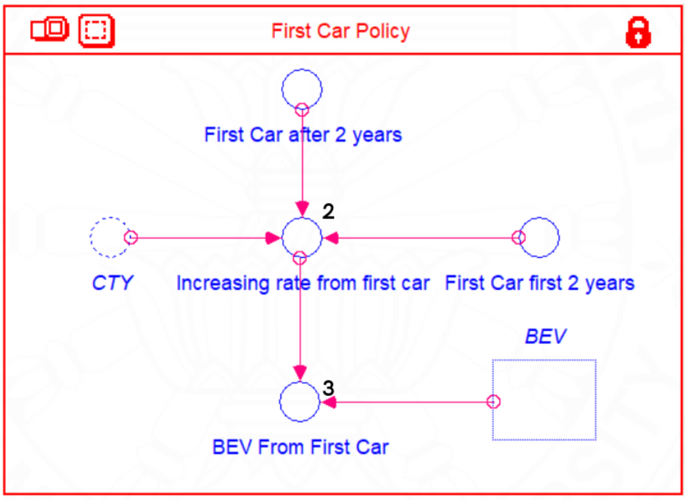


Figure 4.2 First Car Policy.

Increasing_rate_from_first_car = IF Year = 0 OR Year = 1 THEN First_Car_first_2_years
ELSE IF Year < 5 AND Year > 1 THEN First_Car_after_2_years ELSE 0 [2]

*BEV_From_First_Car = ROUND(BEV*Increasing_rate_from_first_car)* [3]

Many governments have initiated and implemented policies to stimulate and encourage BEVs production and adoption (Sierzchula et al., 2014). An annual tax policy will develop on the amount of money that can be saved from the average of taxes reduction for both BEVs category weights. Then the amount of saved money from annual taxes will be divided by average car prices and the result is getting the total increase in BEVs for both categories. Convert the total increase in BEVs into a percentage to apply to the annual tax policy model. The amount of cars is rising high due to tax reduction in the first ten years with a low increase rate in the first five years and higher in the following five years [4] [5].

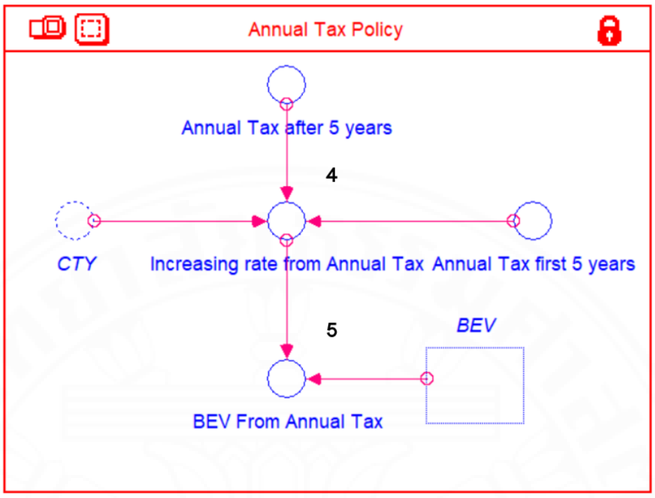


Figure 4.3 Annual Tax Policy.

Increasing_rate_from_Annual_Tax =

IF Year >= 0 and Year < 5 THEN Annual_Tax_first_5_years

ELSE Year >= 5 and Year <= 10

*THEN (Annual_Tax_after_5_years*Annual_Tax_first_5_years) + Annual_Tax_first_5_years*

ELSE Annual_Tax_first_5_years [4]

BEV_From_Annual_Taxes =

*ROUND(BEV*Increasing_rate_from_Annual_Tax)* [5]

To create a reliable model, using the same performance car as conventional and BEV cars, MG ZS and MG ZS BEV (Auto for fun, 2020) (Blink-Drive, 2019), to evaluate the amount of saving from the import taxes by using the average import taxes.

The import tax policy model will use the amount of saving from the average of taxes reduction for both BEVs category weights. Then the amount of saving from import taxes will be divided by average car prices and the result is getting the total increase in BEVs for both categories. After that, convert the total increase in BEVs into a percentage for application to the import tax policy model. The amount of cars is rising high due to tax reduction in the first five years with a high increase rate in the first two years and low in the following three years [6] [7].

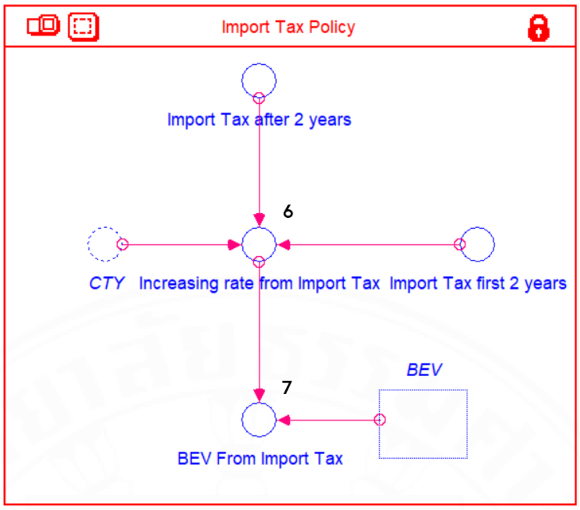


Figure 4.4 Import Tax Policy.

Increasing_rate_from_Import_Tax =
IF Year = 0 or Year = 1 THEN Import_Tax_first_2_years
ELSE IF Year < 5 and Year > 1
THEN Import_Tax_after_2_years ELSE 0 [6]

BEV_From_Import_Taxes =
*Round(BEV*Increasing_rate_from_Import_Tax)* [7]

The number of BEVs from each factor sum up to be an inflow to the BEVs stock to cumulate the number of BEVs each ending year [8].

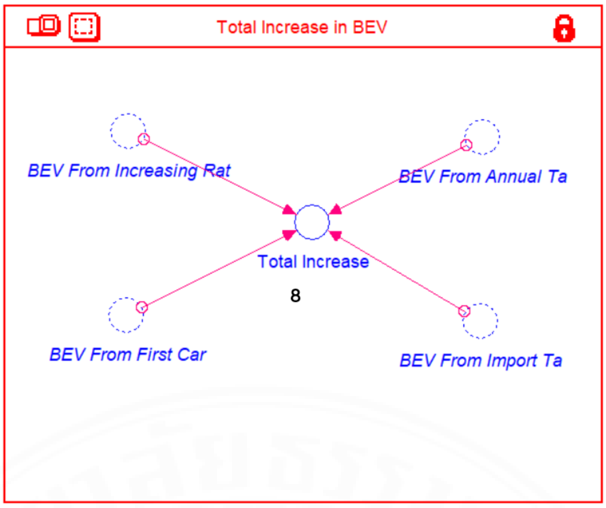


Figure 4.5 Total Increase in BEV.

Total_Increase = BEV_From_Increasing_Rate + BEV_From_First_Car + BEV_From_Annual_Taxes +BEV_From_Import_Taxes *[8]*

CHAPTER 5
SIMULATION RESULT

After simulating and run a dynamic model of the demand for BEVs in Thailand for 15 years will result in the year 2036; the target year set as a goal of this research to observe the amount of total BEVs and the increase of BEVs by each factor to see if it reaches the target.

As a result, including the amount BEVs from each factor each year with the annual increase from market trend and indirect support from the government and the total amount of cumulative BEVs each ending year. The three critical factors included in this result are first car policy, annual tax policy, and import tax policy.

Table 5.1 Simulation result base model(policies1+2+3)

Years	*Beginning BEVs*	*Ending BEVs*	*BEV From First Car*	*BEV From Annual Tax*	*BEV From Import Tax*	*BEV From Increasing Rate*
2022	*3,994*	*7,820*	*518*	*342*	*2,298*	*668*
2023	*7,820*	*15,311*	*1,013*	*670*	*4,500*	*1,308*
2024	*15,311*	*22,613*	*1,654*	*1,312*	*1,774*	*2,562*
2025	*22,613*	*33,396*	*2,442*	*1,938*	*2,620*	*3,783*
2026	*33,396*	*49,322*	*3,607*	*2,862*	*3,870*	*5,587*
2027	*49,322*	*61,843*	*0*	*4,269*	*0*	*8,252*
2028	*61,843*	*77,542*	*0*	*5,353*	*0*	*10,346*
2029	*77,542*	*97,227*	*0*	*6,712*	*0*	*12,973*
2030	*97,227*	*121,909*	*0*	*8,416*	*0*	*16,266*
2031	*121,909*	*152,856*	*0*	*10,552*	*0*	*20,395*
2032	*152,856*	*191,660*	*0*	*13,231*	*0*	*25,573*
2033	*191,660*	*240,150*	*0*	*16,425*	*0*	*32,065*
2034	*240,150*	*300,908*	*0*	*20,581*	*0*	*40,177*
2035	*300,908*	*377,038*	*0*	*25,788*	*0*	*50,342*
2036	*377,038*	*472,428*	*0*	*32,312*	*0*	*63,078*

From the table, the first column represents the year start from 2022 to 2036. The next five columns show the amount of EVs from each factor. The seventh column represents the annual increase in EVs from market trends and indirect support from the government, and the eighth column is the sum of each increase from factors and the annual increase in that year. The last column is the total amount of EVs at the ending of each year.

There are three possibilities to reach the goal target of 400,000 BEVs. The first one is to implement all the policies together which is policies 1+2+3 which is the first car policy, annual tax policy, and import tax policy. When policies 1+2+3 which are the first car policy, annual tax policy, and import tax policy are used the goal target can be reached or even better in the meantime. Implementing all the policies at the same time are required a high amount of budget and constant effort of Thai government reach the goal target. Therefore there are different scenario of policies implemented together that can reach the goal target and have fewer requirements for the Thai governments.

Table 5.2 Simulation result (policies1+2)

Years	*Beginning BEVs*	*Ending BEVs*	*BEV From First Car*	*BEV From Annual Tax*	*BEV From Increasing Rate*
2022	3,994	5,522	518	342	668
2023	5,522	7,635	716	473	924
2024	7,635	10,391	825	654	1,277
2025	10,391	14,142	1,122	891	1,738
2026	14,142	19,247	1,527	1,212	2,366
2027	19,247	24,133	0	1,666	3,220
2028	24,133	30,259	0	2,089	4,037
2029	30,259	37,940	0	2,619	5,062
2030	37,940	47,571	0	3,284	6,347
2031	47,571	59,648	0	4,118	7,959
2032	59,648	74,790	0	5,163	9,979
2033	74,790	93,712	0	6,410	12,512
2034	93,712	117,421	0	8,031	15,678

2035	117,421	147,129	0	10,063	19,645
2036	147,129	184,353	0	12,609	24,615

When using policies 1+2 which are the first cars policy and annual taxes policy the goal target is not satisfied. The total BEVs in 2036 for this scenario is 184,353.

Table 5.3 Simulation result (policies1+3)

Years	*Beginning BEVs*	*Ending BEVs*	*BEV From First Car*	BEV From Import Taxes	*BEV From Increasing Rate*
2022	3,994	7,478	518	2,298	668
2023	7,478	14,001	969	4,303	1,251
2024	14,001	19,477	1,512	1,622	2,342
2025	19,477	27,097	2,104	2,257	3,259
2026	27,097	37,696	2,926	3,140	4,533
2027	37,696	44,003	0	0	6,307
2028	44,003	51,365	0	0	7,362
2029	51,365	59,958	0	0	8,593
2030	59,958	69,989	0	0	10,031
2031	69,989	81,698	0	0	11,709
2032	81,698	95,366	0	0	13,668
2033	95,366	111,321	0	0	15,955
2034	111,321	129,945	0	0	18,624
2035	129,945	151,685	0	0	21,740
2036	151,685	177,062	0	0	25,377

When using policies 1+3 which are the first cars policy and import taxes policy the goal target is not satisfied. The total BEVs in 2036 for this scenario is 177,062.

Table 5.4 Simulation result (policies2+3)

Years	*Beginning BEVs*	*Ending BEVs*	BEV From Annual Taxes	BEV From Import Taxes	*BEV From Increasing Rate*
2022	3,994	7,302	342	2,298	668
2023	7,302	13,351	626	4,201	1,222

2024	13,351	18,276	1,144	1,547	2,234
2025	18,276	25,018	1,566	2,118	3,058
2026	25,018	34,247	2,144	2,899	4,186
2027	34,247	42,941	2,964	0	5,730
2028	42,941	53,842	3,717	0	7,184
2029	53,842	67,510	4,660	0	9,008
2030	67,510	84,647	5,843	0	11,294
2031	84,647	106,135	7,327	0	14,161
2032	106,135	133,078	9,187	0	17,756
2033	133,078	166,747	11,405	0	22,264
2034	166,747	208,934	14,290	0	27,897
2035	208,934	261,795	17,906	0	34,955
2036	261,795	328,029	22,436	0	43,798

When using policies 2+3 which are annual taxes policy and import taxes policy the goal target is not reached. The total BEVs in 2036 for these policies is 328,029. This is likely to have a possibility to reach the goal target according to current use policies that have already implemented are annual taxes policy reduced up to 40% and import tax policies up to 50%. Both policy policies are still slightly below the goal target. To reach the goal target in some foreign countries annual tax policy can be reduced up to 100% and import tax can be reduced up to 50%. (The Department for Transport, 2022)

Table 5.5 Simulation result goal target reached(policies2+3)

Years	*Beginning BEVs*	*Ending BEVs*	BEV From Annual Taxes	BEV From Import Taxes	*BEV From Increasing Rate*
2022	3,994	7,622	382	2,578	668
2023	7,622	14,545	729	4,919	1,275
2024	14,545	20,201	1,392	1,831	2,433
2025	20,201	28,057	1,933	2,543	3,380
2026	28,057	38,968	2,685	3,532	4,694
2027	38,968	49,254	3,767	0	6,519

2028	49,254	62,255	4,761	0	8,240
2029	62,255	78,687	6,017	0	10,415
2030	78,687	99,457	7,606	0	13,164
2031	99,457	125,709	9,613	0	16,639
2032	125,709	158,891	12,151	0	21,031
2033	158,891	200,679	15,206	0	26,582
2034	200,679	253,458	19,205	0	33,574
2035	253,458	320,118	24,256	0	42,404
2036	320,118	404,309	30,635	0	53,556

Then after testing policies 2+3 which are the annual taxes policy and import taxes policy. with different percentages of tax reduction, policies 2+3 which are the annual taxes policy and import taxes policy can be reached the goal target of 400,000 BEVs in 2036. While increase tax reduction for the annual taxes policies reduced up to 65% and increase tax reduction import taxes policies up to 50%. The total BEVs in 2036 is 404,309. And this is the second scenarios that can reach the goal targets of the Thai government.

Table 5.6 Simulation result goal target reached(policies1+2)

Years	*Beginning BEVs*	*Ending BEVs*	*BEV From First Car*	*BEV From Annual Tax*	*BEV From Increasing Rate*
2022	3,994	5,809	518	629	668
2023	5,809	8,449	753	915	972
2024	8,449	12,106	912	1,331	1,414
2025	12,106	17,345	1,307	1,907	2,025
2026	17,345	24,852	1,873	2,732	2,902
2027	24,852	32,963	0	3,953	4,158
2028	32,963	43,722	0	5,244	5,515
2029	43,722	57,992	0	6,955	7,315
2030	57,992	76,919	0	9,225	9,702
2031	76,919	102,024	0	12,236	12,869

2032	102,024	135,322	0	16,229	17,069
2033	135,322	179,274	0	21,313	22,639
2034	179,274	237,503	0	28,236	29,993
2035	237,503	314,644	0	37,407	39,734
2036	314,644	416,840	0	49,556	52,640

Furthermore, policies 1+2 which are the first cars policy and annual taxes policy still be can possible to reach the goal target of the Thai government. Which is to implement the first car policy to reduce the price of BEVs by 100,000 baht and implement along with increase tax reduction for the annual taxes policies up to 90% resulting in the total BEVs at the end of the year 2036 can reach 416 thousand and the goal target is reached.

To conclude all the possible scenario that can reach the goal target of the Thai government there are a total of 3 scenarios. Scenario1 of policies 1+2+3 which are the first car policy, annual tax policy, and import tax policy with the first car price reduced up to 100,000baht, tax reduction of annual tax policy reduce up to 50%, and tax reduction of import tax policy reduced up to 40%. Scenario2 policies 2+3 with tax reduction of annual tax policy reduce up to 65% and tax reduction of import tax policy reduced up to 50%. Scenario3 policies 1+2 the first car policy price reduced up to 100,000 baht and tax reduction of annual tax policy reduced up to 90%.

These three policies are possible policies for the Thai government to reach the goal target at this time. nevertheless, some policies required high effort and high investment costs to implement the policies such as the first car policy and an annual tax policy. The first cars needed high budgets to reduce the price of BEVs by 100,000 baht to implement this policy the financial status of the Thai government has to be stable. In the annual tax policy, increasing the tax reduction up to 90% may be not fully adopted in Thailand's situation because the income from annual tax for the transportation department will be greatly reduced and the budget for improving transportation infrastructure will decrease. This result in a slow development of transportation infrastructure. Therefore some of these scenario are extreme cases that hard is to implement.

CHAPTER 6
MODEL VALIDATION

Model validation is the set of processes and activities intended to verify that models are performing as expected (Barata, 2020). This study to validate the model is sensitivity analysis. Sensitivity Analysis (SA) is a method that measures how the impact of uncertainties of one or more input variables can lead to uncertainties on the output variables. (Pichery, 2014)

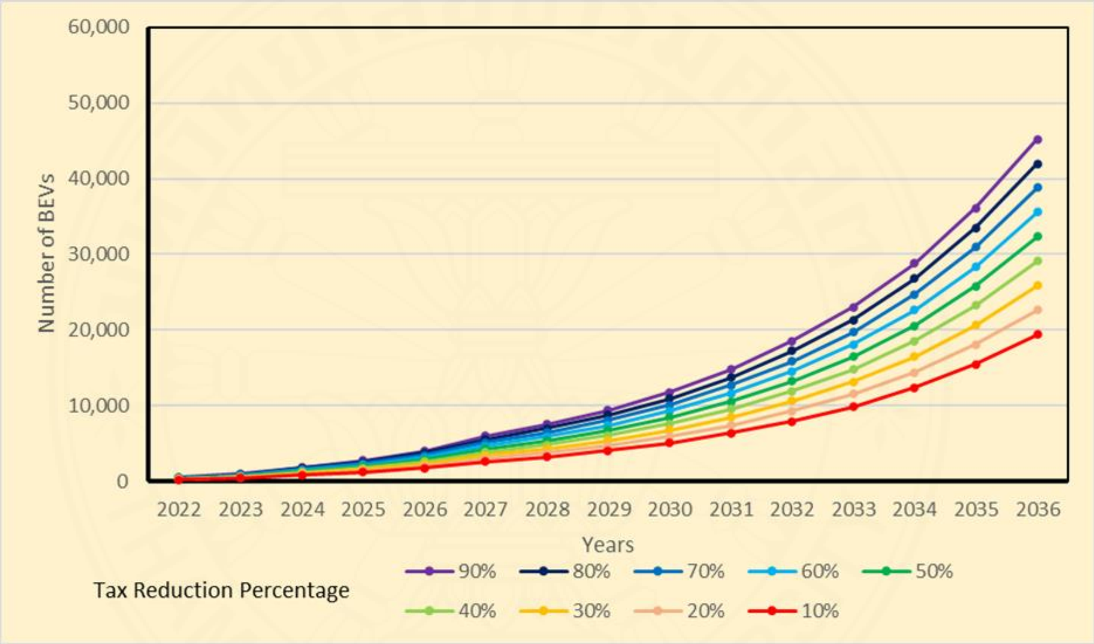


Figure 6.1 Sensitivity for Annual Tax Policy.

Table 6.1 Number of BEV increase compare with tax reduction of Annual Tax Policy

Tax Reduction of Annual Tax Policy	Number of BEVs increase at 2036
90%	45,237
80%	42,006
70%	38,775
60%	35,544
50%	32,312
40%	29,081
30%	25,850
20%	22,619
10%	19,388
20%	25,850
15%	24,234
10%	22,619

From figure 6.1 and table 6.1, this sensitivity analysis is from the base model of scenario1 of policies 1+2+3 which are the first car policy, annual tax policy, and import tax. In this graph, the tax reduction of the annual tax policy has been changed from 50% to 90% to see the sensitivity of the model. While others values are constant as a base model. At the beginning of the graph, the line is a shallow curve and slightly rising, then turning to a steep curve and rising high. The model changes in magnitude only but still can analyze behavior consistency.

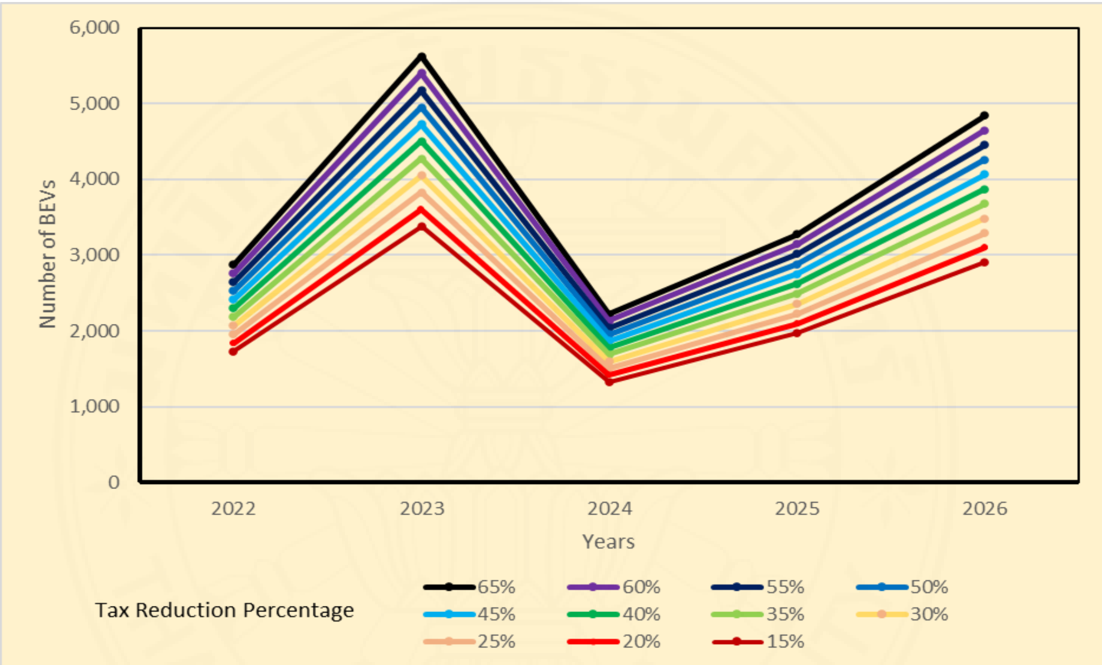


Figure 6.2 Sensitivity for Import Tax Policy.

Table 6.2 Number of BEV increase compare with tax reduction of Import Tax Policy

Tax Reduction for Import Tax Policy	Number of BEVs increase at 2026
65%	4,838
60%	4,644
55%	4,451
50%	4,257
45%	4,064
40%	3,870
35%	3,677
30%	3,483
25%	3,290
20%	3,096
15%	2,903

From figure 6.2 and table 6.2, this sensitivity analysis is from the base model of scenario1 of policies 1+2+3 which are the first car policy, annual tax policy, and import tax. In this graph, the tax reduction of the import tax policy has been changed from 40% to 50% to see the sensitivity of the model. While other values are constant as a base model. At the beginning of the graph, the line is a rising high in the first two years, then the number of increased BEVs drop and rise moderately. The model changes in magnitude only but still can analyze behavior consistency. The result from two factors shows that import tax policy impacts the most in the short term and annual tax policy impacts the most in the long term.

CHAPTER 7
CONCLUSION

To obtain the government's expectations, the simulation is run for fifteen years, resulting in 2036. From the simulation results, three possibilities can reach the goal target which is a scenario1 of policies 1+2+3 which are the first car policy, annual tax policy, and import tax policy with the first car price reduced up to 100,000 baht, tax reduction of annual tax policy reduce up to 50%, and tax reduction of import tax policy reduced up to 40%. Scenario2 policies 2+3 which are an annual tax policy and import tax policy with tax reduction of annual tax policy reduce up to 65% and tax reduction of import tax policy reduced up to 50%. Scenario3 policies 1+2 which are the first car policy and annual tax policy. The first car policy price reduced up to 100,000 baht and tax reduction of annual tax policy reduced up to 90%.

policies 1+2+3 which are the first car policy, annual tax policy, and import tax policy and policies 1+2 which are the first car policy and annual tax policy can reach the goal target or even better but these two scenarios are extreme cases that governments might not implement because of high cost and the information from foreign countries may not be fully adopted in Thailand. Therefore, the most suitable scenario for the Thai government is policies 2+3 with tax reduction of annual tax policy reduce up to 65% and tax reduction of import tax policy reduced up to 50% due to the balance of each policy tax reduction rate.

In this study, the result is that 404,409 BEVs can be increased by implementing a policies 2+3 with tax reduction of annual tax policy reduce up to 65% and tax reduction of import tax policy reduced up to 50% and this scenario has the highest possibility to implement in the current Thailand situation.

CHAPTER 8
LIMITATION

There are some limitations to this study. Data used in the system dynamics model development are based on the Thai government. Literature is from both Thailand and other foreign countries. Some values applied in the system dynamics model are converted from other counties such as annual tax policy and import tax policy. This value may not be fully adopted in Thailand's situation.

Furthermore, the model only mentions about reduction of certain things about the BEVs the annual tax reductions and import tax reductions. There are still possible policies by which the Thai government can increase the number of BEVs user in Thailand such as increasing the annual tax on combustion cars. But the model needs information about the literature reviews or international journals to confirm that there is a possibility to increase the annual tax for combustion cars.

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