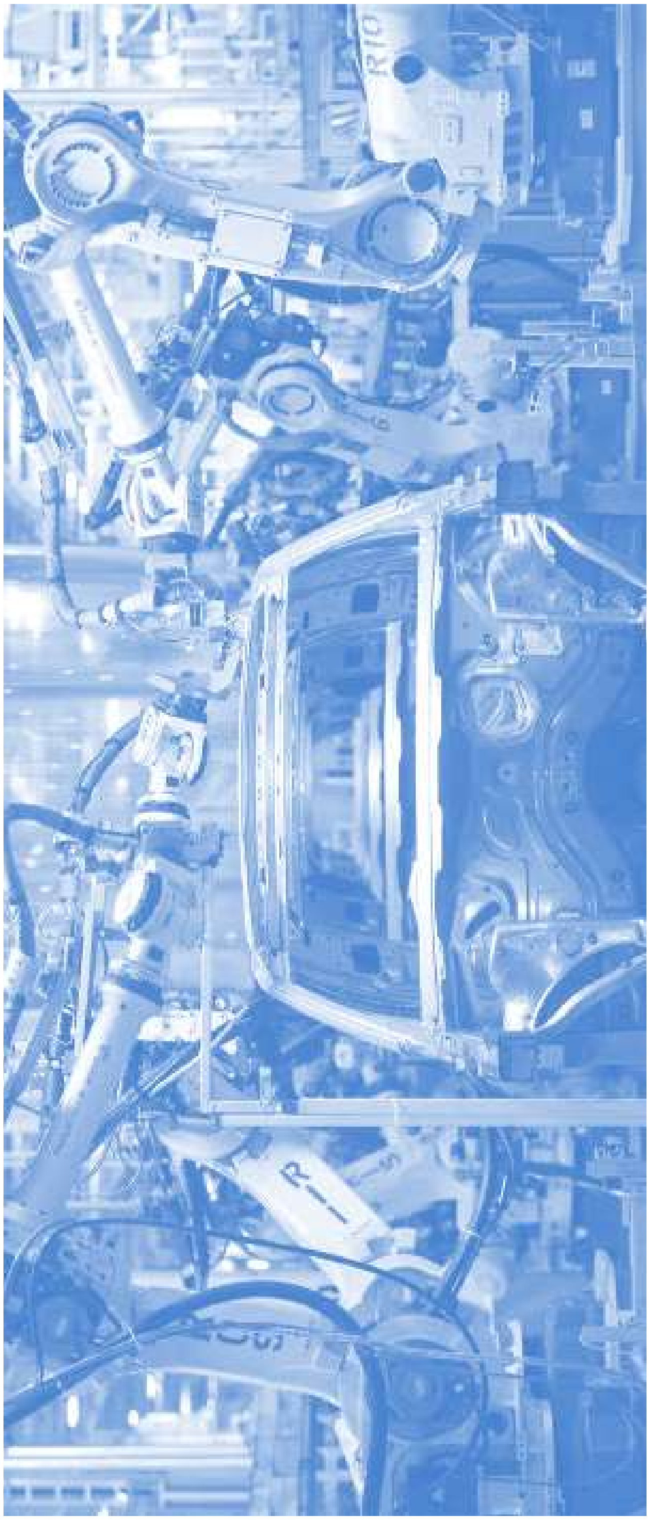


THE FUTURE OF THAILAND'S AUTOMOTIVE INDUSTRY: POLICY CONSIDERATIONS

Panuwat Tajai
Sunthorn Tunmuntong
*Wichsinee Wibulpolprasert**

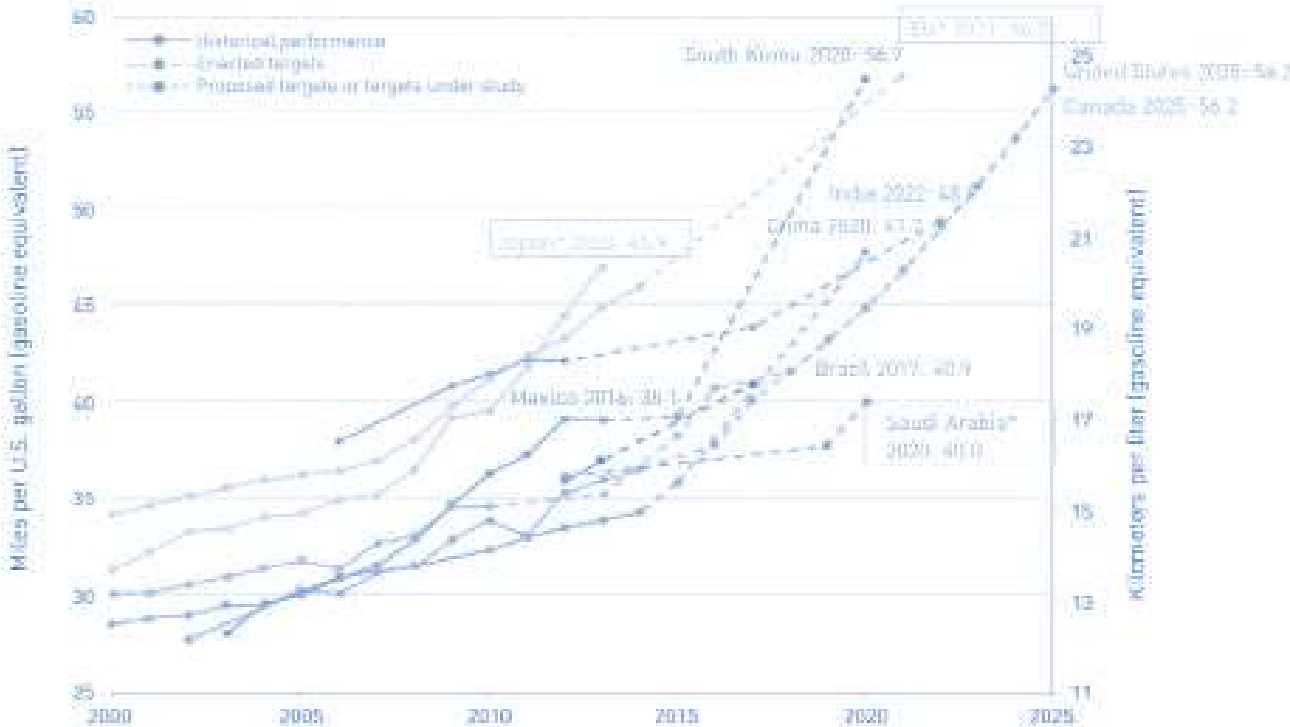
1. INTRODUCTION

In recent years, the landscape of the global automobile industry has undergone a major transition shaped by two megatrends. First, fueled by the global need to mitigate the adverse impacts of climate change and the energy security crisis, many countries are demanding the production of a more energy-efficient and environmentally friendly automobile fleet. Second, technological advancement and modern lifestyles will make connectivity and information technology (IT) the "must-have" functions in cars of the future.

The first trend, the global need for "greener" automobile fleets, manifests itself through the tighter corporate average fuel efficiency (CAFE) standard that many countries have adopted. The CAFE standard stipulates that each automobile manufacturer must produce vehicles that have a weighted average fuel efficiency that is under a specified national standard. Figure 1 displays the past, current, and planned CAFE standards in major automobile markets. There is a clear trend toward much more fuel-efficient automobile fleets in the next 5-10 years.

* *Mr. Panuwat Tajai is researcher, Human Resources and Social Development Program; Mr. Sunthorn Tunmuntong is researcher, Science and Technology Development Program; and Dr. Wichsinee Wibulpolprasert is Research Fellow, Sectoral Economic Program, Thailand Development Research Institute.*

Figure 1: Evolution of the corporate average fuel efficiency (CAFE) standards in major markets



Source: International Council on Clean Transportation.
Note: Boxes indicate Thailand's major export markets.

It has become evident that many conventional automobile producers are struggling to adjust their production of vehicles in response to rising expectations. Recent scandals involving intentional manipulation of fuel efficiency and emission rates of certain types of engines by leading German and Japanese automakers indicate that the conventional fossil-fuel internal combustion engine might have reached its technological frontier. This situation has opened up a window of opportunity for greener technologies, especially electric-powered engines, which range from hybrid engines to pure electric engines.

The second trend, the demand for "smarter" and more connected automobiles, is propelled by technology-enabled changes in consumers' lifestyles. The automotive software and sensors with which vehicles are equipped have advanced to a stage where they can assist the driver in terms of safety and comfort on the road. Moreover, autonomous driving is a foreseeable major step that will reshape the way people commute. Future generations of vehicles will be developed to be connected, think, or even self-drive.

Lacking specialties in IT and artificial intelligence (AI), many existing automobile manufacturers have striven to form partnerships with software and sensor companies in response to the second megatrend. Connectivity features in next-generation automobiles also give rise to a new business model, for example the ride-sharing business. The recent partnerships between automakers, software and sensor developers, and ride-sharing providers can be seen in Figure 2.

Figure 2: Partnership between car/auto parts makers, software and sensor developers, and ride-sharing providers

Partnership	Year
Continental - Google	2013
BMW - Baidu	2014
Volvo - Microsoft	2015
Bosch - Tomtom	2015
Bosch - Google	2015
Volkvagen - GM - Mobileye	2016
BMW - Intel - Mobileye	2016
Toyota - Microsoft	2016
Ford - Pivotal	2016
Delphi - Mobileye	2016
Renault-Nissan - Sylpheo	2016
Volvo - Autoliv	2016
Delphi - Quanergy	2016
Hyundai - Google	In discussions

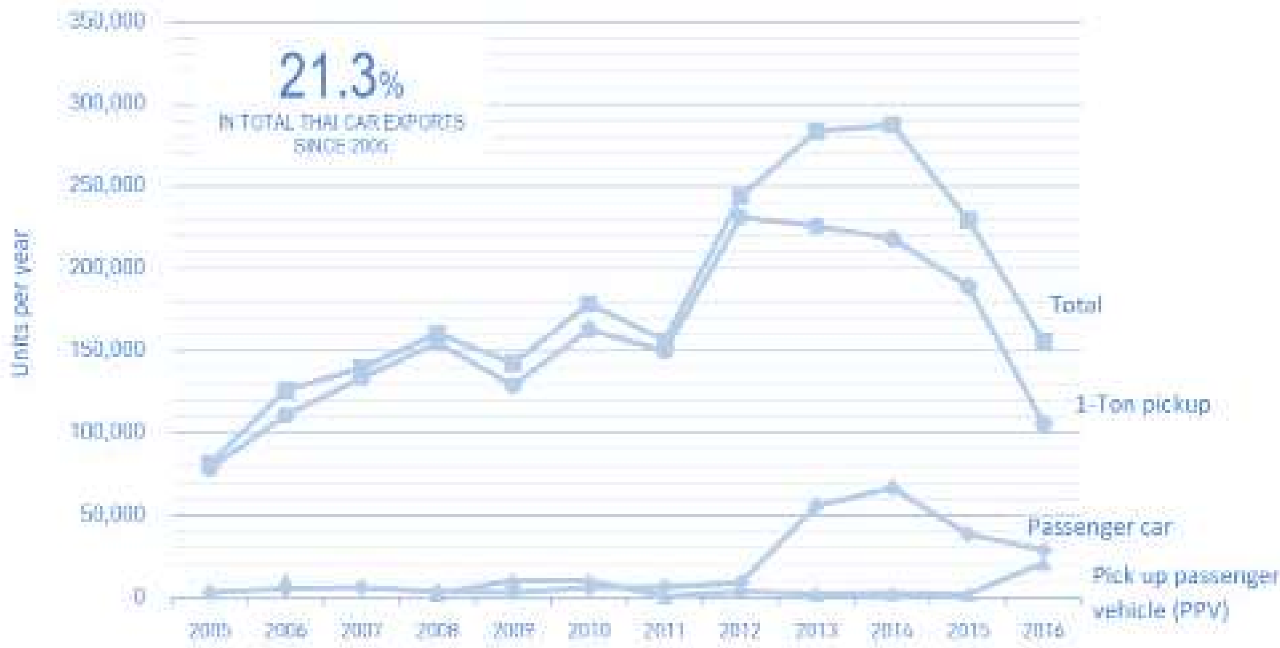
Partnership	Year
BMW - Scoop Technologie	2016
Toyota - Uber	2016
Volkswagen - Gett	2016
GM - Lyft	2016
Volvo - Uber	2016

Source: Authors' compilation from various sources.

Amid the changes driven by the two megatrends, newcomers have successfully penetrated into various positions in the automotive value chain. Promising examples are the electric car assemblers Tesla Motors and BYD, battery makers, such as Panasonic and LG Chem, and automotive IT developers, such as Google, Microsoft and Baidu. In short, the most value-added parts for the next generation of mobility are no longer made in Detroit, but in Silicon Valley, China, and even Israel.

Once dubbed the "Detroit of Asia," Thailand has every reason to be alarmed by these major transitions. The disruptive forces threatening the global auto industry have already been sensed in the country. For instance, the Thai automobile industry suffered a decline in top export products (automobiles and auto parts) in early 2016 (Figure 3). The decline is partly due to the tightening CAFE standard in key markets, especially in the Middle East, which accounts for 21.3 percent of Thailand's total car export between 2005 and 2016.

Figure 3: Thailand's car exports to the Middle East



Source: Thailand Automotive Institute.

Figure 4: Next-generation automotive technology

Source: Authors' definitions.

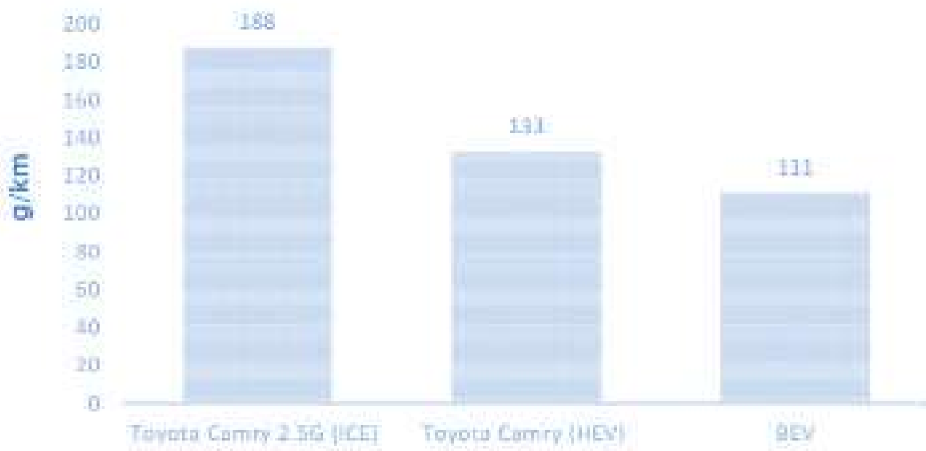
2. NEXT-GENERATION AUTOMOBILES

Next-generation automobile technologies include not only battery-powered electric cars, but also a wide range of new technologies ranging from fuel-efficient ICEs (internal combustion engines), HEVs (hybrid electric vehicles), PHEVs (plug-in hybrid electric vehicles), BEVs (battery-powered electric vehicles), and FCEVs (fuel-cell electric vehicles), as shown in Figure 4.

Even though fuel-efficient ICE vehicles may still exist for the next several decades, it is apparent that electric engines are taking over ICEs as the dominant driving technology. This is because electric engines possess several advantages over ICEs, as shown below:

- Electric engines are more fuel-efficient: Electric engines are more fuel-efficient than ICEs. According to the United States Environmental Protection Agency, all-electric

Figure 5: Carbon dioxide emissions per km in vehicles powered by ICEs, HEVs, and BEVs



Source: Authors' calculations.

Note: Carbon dioxide emissions per km driven take into account tailpipe emissions (for ICE and HEV), as well as emissions for electricity generation (for BEV).

vehicles "convert about 59%-62% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 17%-21% of the energy stored in gasoline to power at the wheels."[1]

- Electric engines need less maintenance: Electric engines consist of many fewer moving parts than ICEs, which are composed of more than 2,000 moving parts. Fewer parts mean less likelihood of malfunctioning that would require maintenance.

- Electric engines alleviate the problem of energy security: Electricity can be produced from various sources, including domestic fuel, especially biomass and other renewables, which makes electricity less susceptible to price fluctuations and supply disruptions compared with gasoline.

- Electric engines are more environmentally friendly: Since electricity can be produced from renewable resources, electric vehicles have a much smaller environmental footprint compared with ICEs that use gasoline. Figure 5 shows the average carbon dioxide emissions per km in vehicles powered by ICEs, as well as HEVs, and BEVs (of the comparable models).

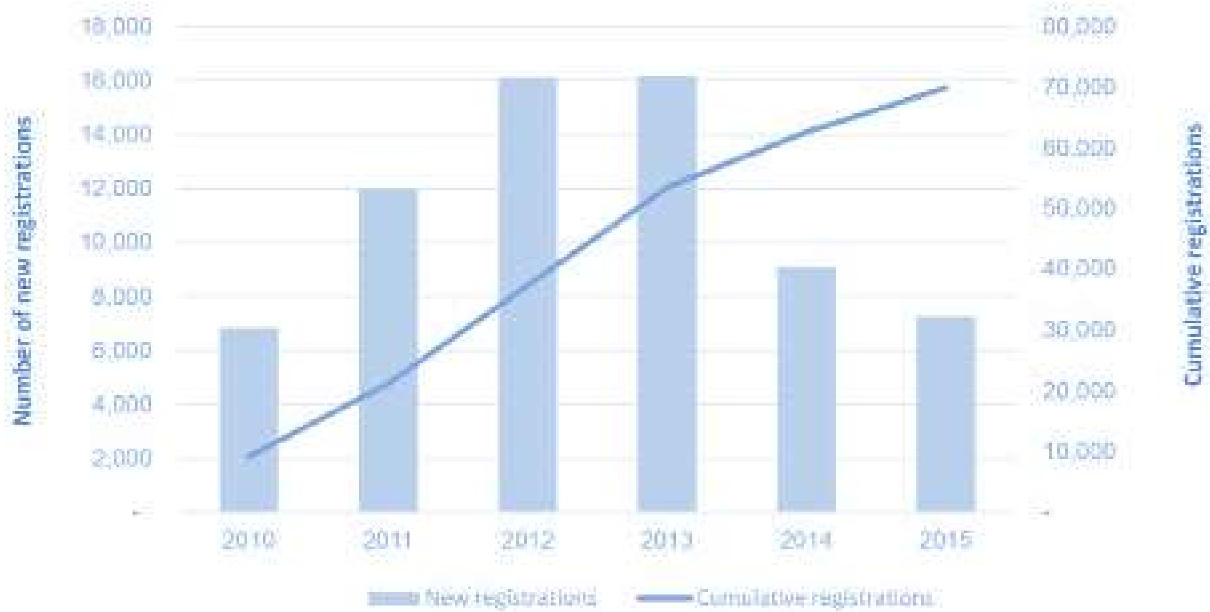
[1] *https://www.fueleconomy.gov/feg/evtech.shtml#end-notes.*

3. CURRENT MARKET SITUATION OF THE NEXT-GENERATION AUTOMOBILES IN THAILAND

Despite the advantages mentioned previously, the market for electric-engine automobiles (HEV, PHEV, BEV, FCEV) is still in its infancy in Thailand.

One of the major obstacles that limits market expansion is the price premium that electric-engine vehicles face over that of most of the popular ICEs. There are two main reasons for this cost disadvantage. First, the majority of electric-engine vehicles have to be imported into Thailand, which adds extra tariff costs to that of the vehicles' base price. Second, the current automobile excise tax structure does not entirely favor environmentally friendly vehicles. These points are elaborated in the following subsections.

Figure 6: New and cumulative HEV registrations, 2010-2015



Source: Department of Land Transport, New Passenger Vehicle Registration.

Potential Impact of Import Tariffs on Domestic Demand

Figures 6 and 7 demonstrate the potential impact of import tariffs on HEV demand. Hybrid electric vehicles (HEVs) were introduced into Thailand in 2007; however, as of 2015, HEVs constituted only a small fraction of all new automobile purchases (less than 2% of the new annual registrations).

Figure 6 indicates that the number of new HEV registrations spiked in 2011 and 2013. The increase in sales was the result of a temporary tariff exemption for important parts, mostly electric drivetrain components, for HEVs that were assembled in Thailand from 2010 to 2013.[2] The tariff exemption effectively reduced the sales price of HEVs by about 20,000 baht per vehicle.[3] After this preferential measure expired, however, the tariffs rebounded to the normal rate, with the maximum rebound rate being 60 percent for certain components.

This observation suggests that a price reduction (through tariff exemption, adjustment of excise tax, or the grant of a purchase tax credit) could be an effective way to expand the domestic market for electric vehicles. Yet, to confirm this relationship, further study on the price elasticity of automobile demand is needed.

Current Automobile Excise Tax does not Favor Environmentally Friendly Vehicles

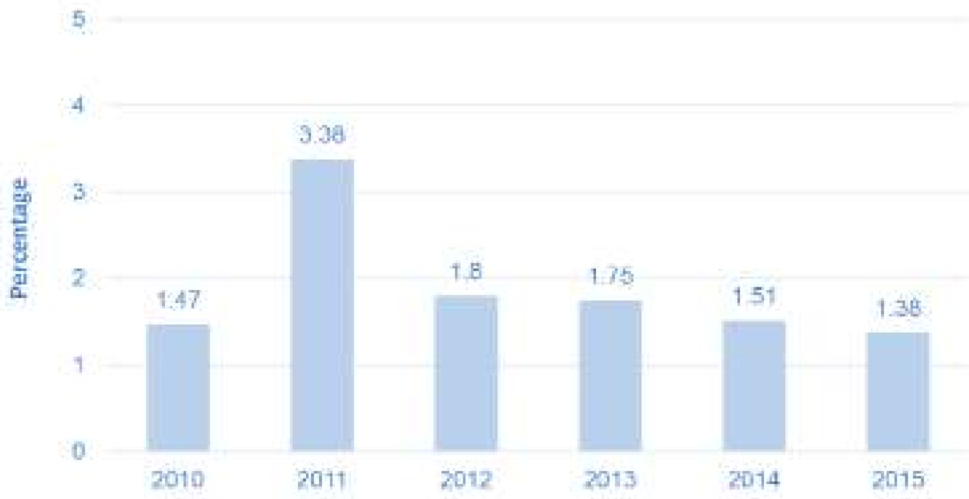
Even though the most recent excise tax structure enacted in early 2016 is claimed to be based on carbon dioxide emissions, our study shows that this is not entirely so. Instead, the current excise tax structure tends to favor one-ton pickups and eco-cars, which are Thai product champions. HEVs, PHEVs, and BEVs, despite the fact that they emit less carbon dioxide than many ICE vehicles, do not necessarily require the payment of lower excise tax.

Figure 8 shows the relationship between the total excise tax payment and the carbon

[2] *See the Royal Thai Government Gazette database [http://www.ratchakitcha.soc.go.th/DATA/PDF/2553/E/121/18.PDF].*

[3] *http://www.manager.co.th/iBizChannel/ViewNews.aspx?NewsID=9530000089606.*

Figure 7: HEVs' share of all new registrations, 2010-2015



Source: Department of Land Transport, New Passenger Vehicle Registration.

dioxide emissions rate for each vehicle model as contained in the Eco-sticker database.[4] Each marker represents all the vehicle models of the same type that have the same carbon dioxide emission rate (in g/km).

If the excise tax is based entirely on the amount of lifetime carbon dioxide emissions, vehicles that emit the same level of carbon dioxide should pay the same amount of tax regardless of the vehicle type. For example, a hybrid car that emits carbon dioxide at a rate of 100 g/km should pay the same amount of tax as an eco-car that emits carbon dioxide at a rate of 100 g/km. Figure 8 demonstrates that this is not necessarily the case. In other words, for the same level of carbon dioxide emissions, eco-cars and pickups require payment of significantly lower excise taxes than other types of vehicles. HEVs and PHEVs, which emit less carbon dioxide than most vehicles in the market, pay much higher excise tax than eco-cars, ICE E85s, and certain traditional ICEs.

Moreover, Figure 8 shows that as the carbon dioxide emissions rate increases, the excise taxes on eco-cars and pickups increase at a much slower rate than other types of vehicles. The shaded ovals depict the rate at which the excise taxes increase in line with carbon dioxide emissions for each type of vehicle. The steeper the oval, the faster the excise tax increases as carbon dioxide emissions increase. In this figure, it is clear that the eco-cars and pickups have the least steep ovals, meaning that their excise taxes do not increase much as carbon dioxide emissions increase. HEVs and PHEVs, on the other hand, do not enjoy equal treatment.

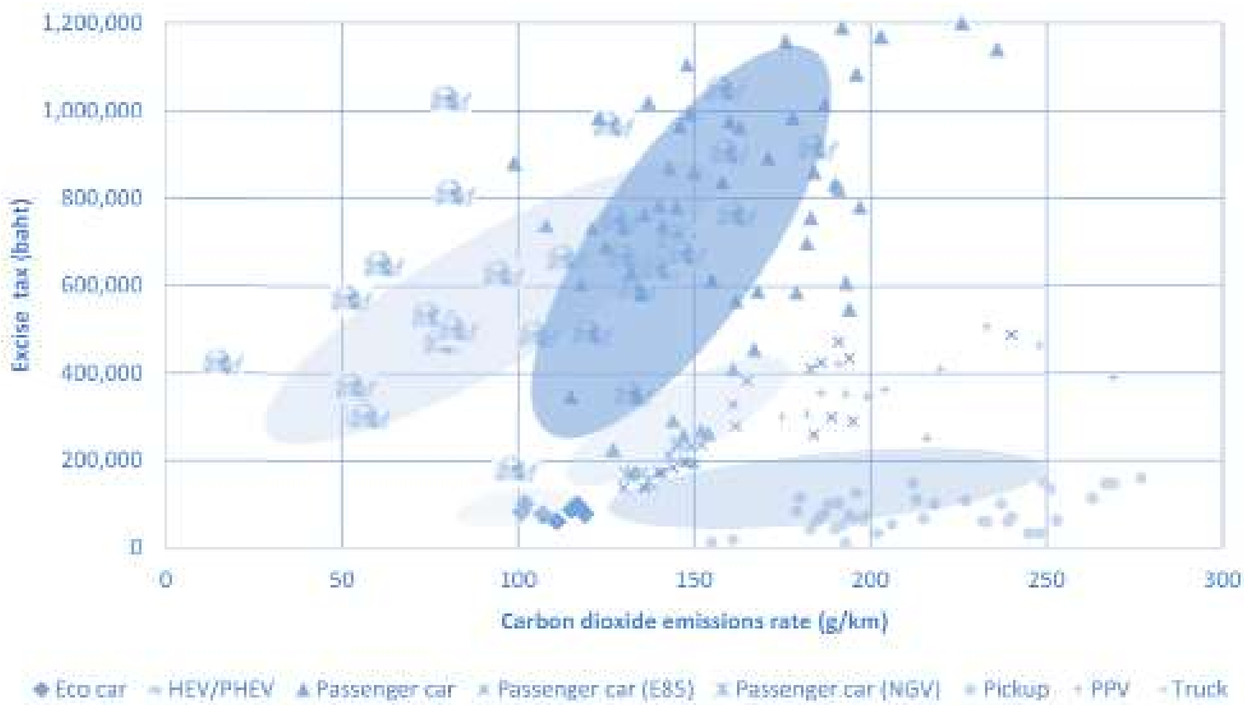
4. SUGGESTED POLICY DIRECTIONS FOR THAILAND

In order to survive the transition and capture emerging opportunities, Thailand should focus on bridging its industrial goal to link with its environmental goal, namely Thailand needs to become the region's producer and exporter of fuel-efficient, environmentally friendly automobiles.

To do so, the government needs to be careful not to pick winners too soon as it is still too early to know which of the next-generation technology types is going to win in the long-run. Instead, a safer bet is to formulate technology-neutral policies that reward low-emission automobile technologies, including efficient ICEs, HEVs, PHEVs, BEVs,

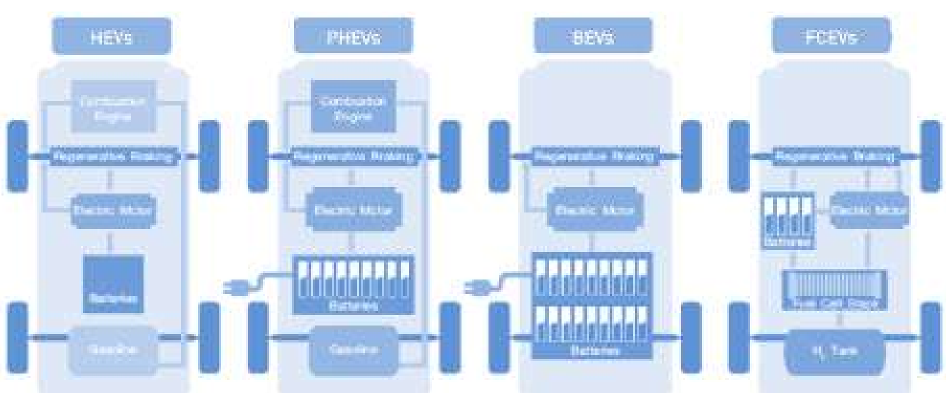
[4] *The "Eco-sticker" is an information tag detailing fuel efficiency, the environmental and safety qualifications of a car for the consumer's benefit. Developed by the Ministry of Industry and launched in 2015, it contains a variety of information, for instance, the fuel consumption rate and carbon dioxide emission rate.*

Figure 8: Average excise tax payment vs. carbon dioxide emissions (g/km)



Source: Office of Industrial Economics, Eco-sticker database. Accessed October 24, 2016.

Figure 9: Essential components of electric-engine automobiles



Source: King Mongkut's University of Technology Thonburi, and National Metal and Materials Technology Center (2015). "Assessment of Electric Vehicle Technology Development and Its Implication in Thailand," February 2015.

and FCEVs. We therefore propose the following strategies.

4.1 Supply-side strategy

Without the relevant technology in hand, Thailand should try to attract foreign investment in **essential components of the next-generation automobiles**, especially batteries and motors. Figure *9* illustrates that batteries and electric motors are common components for HEVs, PHEVs, BEVs, and FCEVs.

The goal is to position Thailand as a base for manufacturing batteries and motors in Southeast Asia. In this way, Thai manufacturers can capture part of the high value added from the new supply chain and get benefits from technological transfer.

One form of financial incentives that can help attract foreign investment is to reduce/exempt import tariffs for components needed to produce batteries and motors. The current tariff structures for components of batteries and motors can be as high as 60 percent (WTO rate) and as low as 0-30 percent (FTA rate).[5] Even though the existing tariffs on components are not exceptionally high, reducing tariff on components still offers the benefit of lowering the purchase price and further boosting domestic demand.

One word of caution, however: the government should avoid taking a shortcut by reducing tariffs for importing completely built up (CBU) vehicles, that is, vehicles which are completely built outside of Thailand. Even though exempting tariffs on CBU vehicles can reduce the domestic price and boost demand for such vehicles, there will be no value added, nor will there be technology transfer opportunities remaining for domestic manufacturers.

Lastly, it is important to emphasize that this supply-side strategy has to complement the following demand-side strategies to be successful in attracting foreign investment.

4.2 Demand-side strategy

Demand-side strategies include any mechanisms that allow environmentally friendly vehicles to become more cost-competitive than traditional ICEs.

The first strategy is to revisit the existing automobile excise tax. As stated previously, the current excise tax structure does not fairly reflect the environmental footprint of each automobile. Thus, one obvious way to give a more competitive edge to the next-generation of environmentally friendly automobile is to recalculate the excise tax based on carbon dioxide emissions.

In Figures 10 and 11, we show that adjusting the excise tax can increase price competitiveness of environmentally friendly cars. We used Toyota Camry (ICE and HEV), Nissan LEAF (BEV), and Tesla Model 3 (BEV) as examples. We chose Toyota Camry because it is a popular HEV model with an ICE counterpart. We also chose Nissan LEAF and Tesla Model 3 as representatives of the BEVs since Nissan LEAF is one of the top-selling BEVs and Tesla Model 3 is positioned as a mass-market BEV that will be released in late 2017.

In this thought experiment, we calculate the life cycle cost of each vehicle. The life cycle cost includes up-front purchse price, lifetime fuel cost, and the newly calculated excise tax that reflects the environmental damage from the tailpipe carbon dioxide emissions.

Life cycle cost = purchase price + NPV fuel + tax on carbon dioxide emissions

Lifetime fuel cost is calculated based on the assumption that each model of vehicle is driven about 3,100 km per month and has a useful lifetime of eight years. The new excise tax is based on the estimated lifetime carbon dioxide emissions of each vehicle multiplied by the social cost of carbon (SCC) at three levels of the discount rate.[6]

It may be noted that the newly calculated excise tax used in this thought experiment is *significantly lower* than the existing excise tax for these vehicles. This is because the existing excise tax reflects other government objectives than just the environmental objective. However, as long as this portion of the tax that reflects other objectives remains the same across relevant car models, the relative price differences calculated here will remain unchanged.

First, compare the Toyota Camry 2.5G

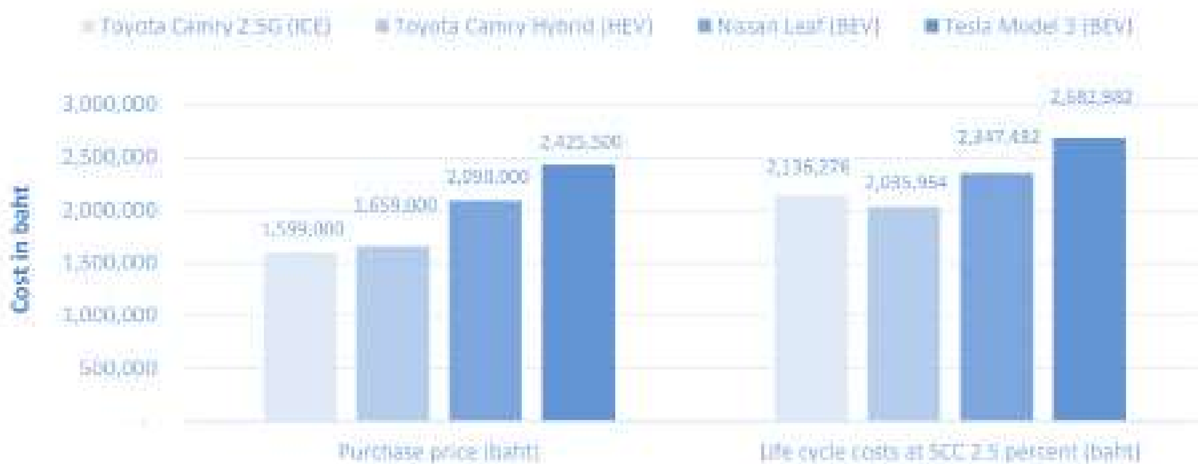
[5] *For more details, see the Thai Customs database [http://igtf.customs.go.th/igtf/viewerImportTariff.do?param=main].*

[6] *For detailed information on the calculations and the assumptions, please refer to Annex I.*

Figure 10: Life cycle cost of Toyota Camry with driving range of 3,100 km/month

Source: Authors' calculations.

Figure 11: Life cycle cost of Toyota Camry vs. Nissan LEAF (BEV) vs. Tesla Model 3 (BEV) at 3,100 km/month



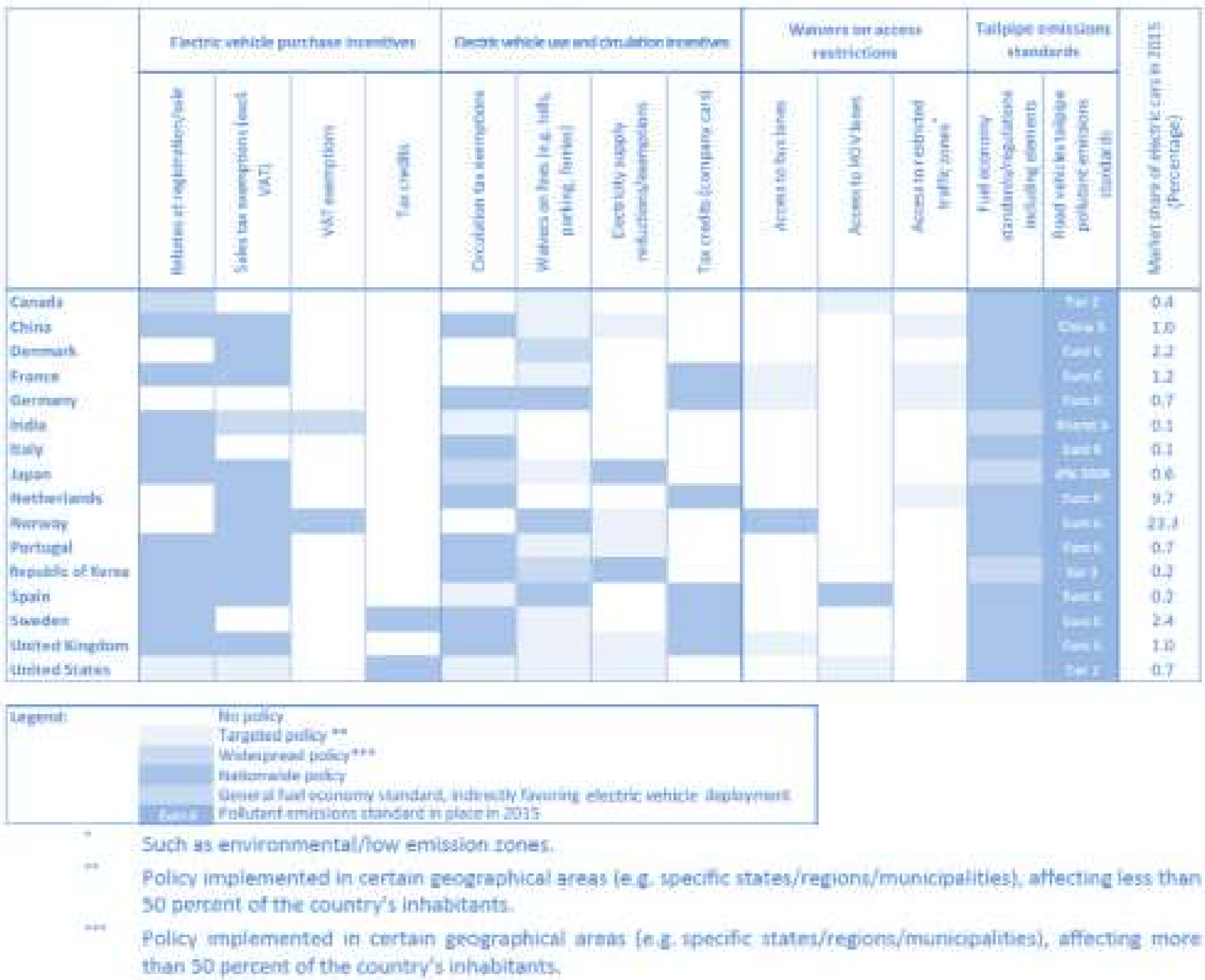
Source: Authors' calculations.

(ICE) to the Toyota Camry Hybrid in Figure 10. The purchase price of the Toyota Camry Hybrid is 60,000 baht more expensive than its ICE counterpart. However, when adjustment is made for the tailpipe carbon dioxide emissions ("purchase price plus optimal tax"), the Hybrid model now would cost only 26,200 baht more. Lastly, when adjustment is made for the tailpipe carbon dioxide emissions and the lifetime fuel cost ("life cycle costs at SCC 2.5 percent"), the Hybrid model becomes cheaper than its ICE counterpart by 100,323 baht.

This exercise shows that, with the proper tax structure that reflects environmental damage and consumers' awareness of lifetime fuel savings, the Toyota Camry Hybrid can easily become cost-competitive with its ICE counterpart without needing additional incentives.

Next, Figure 11 shows a comparison of the Toyota Camry with the Nissan LEAF and Tesla Model 3. Adjusting for the lifetime fuel cost and carbon dioxide emissions reduces the price differences between the BEVs and the ICE/HEVs

Figure 12: Summary of policy support mechanisms for electric vehicle uptake in place in selected countries in 2015



Source: International Energy Agency (IEA). "Global EV Outlook 2016: Beyond One Million Electric Cars."

("life cycle costs at SCC 2.5%"). However, the price premium for the BEVs is still significant, which suggests that additional incentives might be needed to make the cost of BEV competitive, which leads to the proposed **second strategy**.

The **second demand-side strategy** includes granting subsidies or tax incentives to consumers who purchase these environmentally friendly vehicles that are not currently price-competitive with traditional ICE vehicles. The purchase incentive scheme is a popular mechanism used in the United States, Europe, and Japan (see Figure 12). For example:

- *United States*: The United States government gives a maximum tax credit of $7,500 for grid-enabled vehicles (limited to the first 200,000 vehicles per manufacturer).

- *United Kingdom*: Customers who purchase BEVs receive a purchase incentive of up to £4,500 (or $6,300), while customers who purchase PHEVs priced below £60,000 (or $84,000) receive a purchase incentive equal to £2,500 (or $3,500).

Table 1: Subsidy required to make BEVs (Nissan LEAF and Tesla Model 3) price-competitive with an ICE (Toyota Camry)

	Purchase price (baht) [A]	Competitive price (baht) [B]	Subsidy required [A] – [B]
At SCC 5%	2,257,750	1,840,474	417,276
At SCC 3%	2,257,750	1,862,827	394,923
At SCC 2.5%	2,257,750	1,878,794	378,956

Source: Authors' calculations. The purchase price of BEVs is the average price of the Nissan LEAF and Tesla Model 3.

- *Japan*: Japanese purchase subsidies are calculated based on the price difference between an electric vehicle and a comparable ICE, with a maximum subsidy of $7,800.

In the next exercise, we calculate the amount of the subsidy (i.e., tax credits) needed to make BEVs (Nissan LEAF and Tesla Model 3) price-competitive with traditional ICEs (Toyota Camry 2.5G). We define the competitive price for a BEV to be the up-front purchase price that makes the life cycle cost of the BEV equal to the life cycle cost of the ICE.[7] In other words:

Competitive price for BEV = life cycle cost of ICE - NPV fuel of BEV - tax on carbon dioxide emissions of BEV

The difference between the current purchase price for a BEV and the competitive price for a BEV is the subsidy needed to make the BEV price-competitive.

Table 1 suggests that *given the newly calculated carbon dioxide-based excise tax, the lifetime fuel cost, and the current BEV/ICE purchase prices, BEVs need an additional subsidy of about 400,000 baht per vehicle to be cost-competitive with a comparable ICE.*

[7] *Note that the lifecycle cost here includes the newly calculated carbon dioxide-based excise tax proposed previously.*

4.3 Software and automation: value-added opportunities that should not be overlooked

Assumed to be the largest automotive software developer in Southeast Asia, Thailand has huge potential to capture the value added from the software and automation trends required for the next generation of automobiles. This is due to the wage advantage of Thai computer engineers that attracted Japanese automakers to build their software units in Thailand approximately 10 years ago. Over time, the software units in Thailand have progressed from doing a single low value-added task to high-value tasks, such as managing the whole process from the design state to implementing, and testing of automotive software that controls the powertrain, especially for models that are assembled domestically.

Despite its prior advantages in software and automation in the region, Thailand is facing two major challenges in retaining human resources in this area. The first challenge is the rising wage competition from other domestic industries. Interviews with automotive software firms revealed that there are shortages of highly skilled computer engineers in the market. Talented engineers would opt for more highly paid positions in banking, consulting, or related industries. Existing engineers, especially those who are newly graduated, often need intensive in-house training and fail to perform up to their full potential in the first year of employment. The second challenge is the rising wage competition from Vietnam and the Philippines, which are producing equally highly

THERE ARE THREE MAJOR REASONS TO EXPECT SLOW ADOPTION OF BEVS IN THAILAND. FIRST, CURRENT BATTERY TECHNOLOGY CAN OPERATE ONLY FOR A LIMITED RANGE, AND IT TAKES A LONG TIME FOR VEHICLES TO CHARGE. THESE CONSTRAINTS MAKES IT DIFFICULT FOR BEVS TO SUIT THE VARIOUS RANGE OF TRANSPORTATION NEEDS IN THAILAND, ESPECIALLY IN VIEW OF THE EXISTING HEAVY TRAFFIC CONDITIONS.

skilled labor with comparable or even lower wages than that of Thai engineers.

Together, these challenges imply that the government needs to be more strategic about producing and retaining highly skilled labor in this area to fully take advantage of forthcoming opportunities.

4.4 BEV infrastructure: investing the right amount at the right time

In preparation for the transition, the government's initiative to invest in charging for the infrastructure needed for BEVs is a step in the right direction. However, the government should be careful not to invest too much too early, as we believe that a few more years will be required for BEVs to become widespread in Thailand.

There are three major reasons to expect slow adoption of BEVs in Thailand. First, current battery technology can operate only for a limited range, and it takes a long time for vehicles to charge. These constraints makes it difficult for BEVs to suit the various range of transportation needs in Thailand, especially in view of the existing heavy traffic conditions. Second, the cost of production and hence the purchase price of BEVs are still higher than most ICEs and HEVs. Lastly, the price of gasoline is projected to remain moderate over the next few years, making the purchase of BEVs less attractive.

Combine these facts with the results from section 4.2 on demand-side strategy, market trends emphasize the likelihood that HEVs will become mainstream automobiles in the short to medium term, while BEVs might phase in over a longer time horizon. Thus, the current effort to encourage investment in 100 BEV charging stations during the next three years might result in infrastructure that sits relatively idle for the next several years.

5. CONCLUSION

It is apparent that next-generation consumers are expecting much greener and smarter automobiles than the types available today. As an automobile exporter, Thailand has received a warning sign as its product champion, one-ton pickups, struggled to make sales in key markets with tightened new environmental standards.

The key to the survival of Thailand's auto industry is to align the industrial goal with the environmental goal. In other words, Thailand needs to become Southeast Asia's manufacturing hub for next-generation, environmentally friendly automobiles. The transition strategies include lowering tariffs for essential components for manufacturing electric batteries and motors, and giving price incentives to boost domestic demand for environmentally friendly automobiles. Moreover, the government should capitalize on

Table A1: Social cost of carbon value: 2017 (US dollars/metric ton of carbon dioxide)

Discount rate year	5% average	2.5% average	3% average
2017	11	59	39

the competitive advantage that Thai entrepreneurs have in the area of software and automation for automobiles. Lastly, given the likelihood that the market for BEVs will take some time to expand, we recommend that the government rethink the timing of its investment in BEV infrastructure.

Annex I

The interagency process that developed the original United States government social cost of carbon (SCC) estimates is described in the 2010 interagency technical support document of the Interagency Working Group on Social Cost of Carbon 2010. Through that process, the Interagency Group selected four SCC values for use in regulatory analyses. Three of the values are based on the average SCC from three integrated assessment models (IAMs), at discount rates of 2.5%, 3%, and 5%.

Assumptions

- All types of cars are designed to give satisfaction to consumers equally, but consumers consider only the life cycle costs of cars. Therefore, consumers decide to buy cars that must have the lowest costs throughout the life cycle costs.
- The project used in the calculation is determined according to the lifetime of the car. The performance of the car is determined by the lifetime of the battery, which can be used on average for eight years. So the calculation will be use a project life of eight years.
- Lifetime driven[8] = 1,500 and 3,100 km/month
- Discount rate MLR = 7%
- Exchange rate (2017) = 35 baht/US dollar
- Price of fuel (E20)[9] = 22.18 baht/liter
- Retail electricity rate = 4 baht/kWh.
- Energy cost rate:
  ICE = 0.08 liter/km
  HEV = 0.056 liter/km
  BEV = 0.198848 kWh/km
  For electric vehicle, assume 0.32 kWh/miles (100 km = 62.14 miles).[10]
- Price:
  Toyota Camry 2.5G (ICE) = 1,599,000 baht
  Toyota Camry (HEV) = 1,659,000 baht
  Nissan LEAF (BEV) = 2,090,000 baht
  Tesla Model3 (BEV) = 2,425,500 baht
- Current tax:
  Toyota Camry 2.5G (ICE) = 559,650 baht
  Toyota Camry (HEV) = 331,800 baht
  Nissan LEAF (BEV) = 209,000 baht
  Tesla Model 3 (BEV) = 242,550 baht
- Carbon dioxide (CO2) emissions:
  Toyota Camry 2.5G (ICE) = 188 g/km or 0.000188 metric ton/km
  Toyota Camry (HEV) = 133 g/km or 0.000133 metric ton/km
  BEV = 111.35 g/km or 0.000111 metric ton/km
- Discount rate SCC 2017:
  5% = 11.00 $/metric ton of CO2 or 385 baht/metric ton CO2
  3% = 39.00 $/metric ton of CO2 or 1,365 baht/metric ton CO2
  2.5% = 59.00 $/metric ton of CO2 or 2,065 baht/metric ton CO2
- The example vehicles used in the calculation are Toyota-Camry (ICE), Toyota-Camry (HEV), Nissan-LEAF (BEV) and Tesla Model 3

[8] *Lifetime driven = cost of fuel/(energy cost rate*price of fuel). Cost of fuel and energy cost rate are available from www.car.go.th.*

[9] *Authors' calculation by average price of fuel (E20) 2016 – January 2017.*

[10] *http://www.afdc.energy.gov/vehicles/electric_emissions_sources.html.*

Annex II

Tax based on carbon dioxide emissions = emissions of carbon dioxide (CO_2) (metric ton CO_2/km) * lifetime driven (km/year) * Social cost of carbon value (baht/ metric ton of CO_2)

Life cycle costs of cars = fixed cost (price) + net present value of fuel + tax based on CO_2 emissions

Table AII-1: Life cycle costs of cars (baht), 3,100 km/month

	Toyota Camry 2.5G (ICE)	Toyota Camry Hybrid (HEV)	Nissan LEAF (BEV)	Tesla Model 3 (BEV)
Life cycle costs at SCC 5%	2,042,282	1,969,458	2,291,809	2,627,309
Life cycle costs at SCC 3%	2,097,112	2,008,247	2,324,285	2,659,785
Life cycle costs at SCC 2.5%	2,136,276	2,035,954	2,347,482	2,682,982

Table AII-2: Life cycle costs of cars (baht), 1,500 km/month

	Toyota Camry 2.5G (ICE)	Toyota Camry Hybrid (HEV)	Nissan LEAF (BEV)	Tesla Model 3 (BEV)
Life cycle costs at SCC 5%	1,813,492	1,809,222	2,187,649	2,523,149
Life cycle costs at SCC 3%	1,840,022	1,827,991	2,203,364	2,538,864
Life cycle costs at SCC 2.5%	1,858,972	1,841,397	2,214,588	2,550,088

Competitive price for BEV = fixed cost of ICE (price) + NPV fuel of ICE + tax on emissions of CO_2 of ICE - NPV fuel of BEV - tax on emissions of CO_2 of BEV

Subsidy for electric cars = life cycle costs of ICE - life cycle costs of BEV

Table AII-3: Subsidy required for making BEVs (Nissan LEAF and Tesla Model 3) price competitive with ICE (Toyota Camry), 3,100 km/month

	Purchase price (baht) [A]	Competitive price (baht) [B]	Subsidy required [A] – [B]
At SCC 5%	2,257,750	1,840,474	417,276
At SCC 3%	2,257,750	1,862,827	394,923
At SCC 2.5%	2,257,750	1,878,794	378,956

Table AII-4: Subsidy required for making BEVs (Nissan LEAF and Tesla Model 3) price-competitive with ICE (Toyota Camry), 1,500 km/month

	Purchase price (baht) [A]	Competitive price (baht) [B]	Subsidy required [A] – [B]
At SCC 5%	2,257,750	1,715,842	541,908
At SCC 3%	2,257,750	1,726,658	531,092
At SCC 2.5%	2,257,750	1,734,384	523,366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