CHAPTER 1 INTRODUCTION

For over a decade, not only have people been expressed their concerns over the issue of rising oil prices, but also have anxieties about greenhouse gas emitted by transportation sector which has remained mostly widespread. The world energy situation and global warming put pressure on many countries to find feasible solutions. Developing technology to use fossil fuels more efficiently while reducing pollution emissions or switching from carbon neutral and negative fuels usage to alternative fuels are such good examples of energy technology innovation.

1.1 Background

Greenhouse gases (sometimes abbreviated GHGs) are any of various gaseous constituents of the atmosphere, both natural and anthropogenic, which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation. This property traps heat in the atmosphere, and contributes to the global warming.

Concerning this important environmental problem, the international agreement called "Kyoto Protocol" was adopted on 11 December 1997 and entered into force on 16 February 2005. This agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC) commits its parties by setting reduction targets of internationally binding emission. The targets cover the emissions of the six main greenhouse gases, namely: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6).

In 2010, United States Environmental Protection Agency estimated the total national GHG emissions and removals associated with human activities. The primary sources of GHG emissions in the United States are electricity production (34%), transportation (27%), industry (20%), businesses and homes (11%), and agriculture (7%).

In case of Thailand, Thailand is classified into *Non-annex 1 country*, which has no binding target to reduce GHG emissions but has to submit Inventory Report as part of National Communication to UNFCCC database.

According to *2nd National Communication of GHG Inventory in Thailand* (JGSEE, 2010) prepared for Office of Natural Resources and Environmental Policy and Planning (ONEP), the estimation of GHG the emission during 2000 – 2004 was done by using 3 guidelines namely: Revised 1996 IPCC Guidelines for National Greenhouse Gas, 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, and 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry. The primary source of GHG emissions is energy sector (as shown in figure 1.1) and the top three of this sector are energy industry (41.7%), transportation (28.0%) manufacturing industries, and construction (19.3%) respectively

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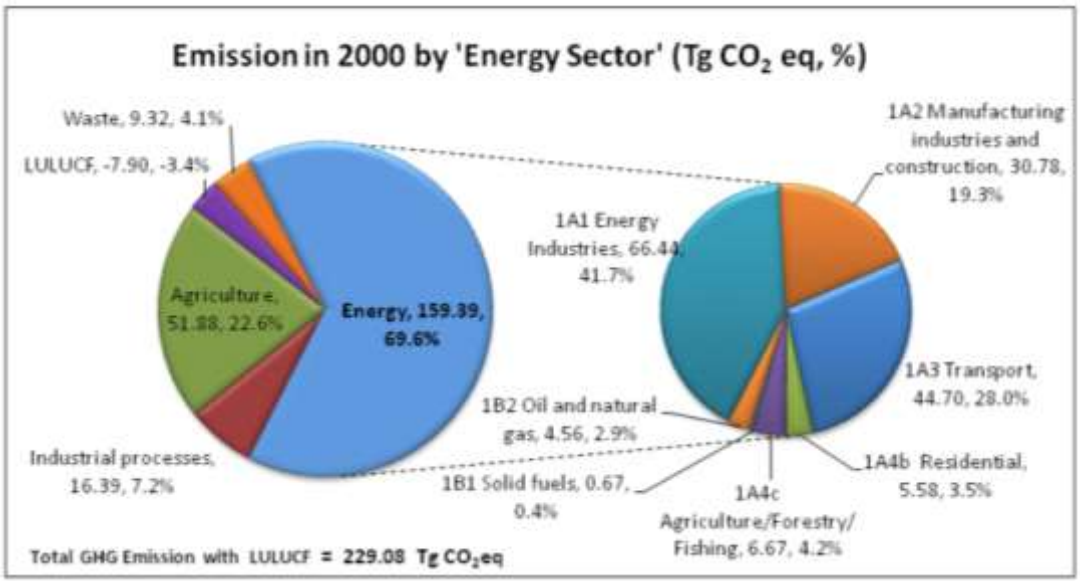

Figure 1.1 GHG Emissions
Source: Thailand's Second National Communication under the United Nations Framework Convention on Climate Change (2011)

Anyways, the biggest culprit behind global warming among these GHGs since the beginning of the Industrial Revolution is carbon dioxide (CO_2) and the majority of the anthropogenic emissions of CO_2 to the atmosphere come from combustion of fossil fuels. (Intergovernmental Panel on Climate Change: IPCC, 2001)

Focusing only on CO_2 emissions, the major sector emitting this kind of GHGs is electric production sector. In case of transportation sector, its CO_2 emission is slightly higher than industry sector even it does not use coal and lignite. Moreover, its increasing rate is relatively high compared to other economic sectors. (Table 1-1)

Table 1.1 CO_2 Emission Classified by Economic Sector

Unit : Million Tons CO_2

Economic Sector	**2010**	**2011**	**Jan – Jun**		**Ratio (%)**			**Change (%)**		
			2011	**2012**	**2010**	**2011**	**2012***	**2010**	**2011**	**2012***
Electric Production	90.0	87.2	44.6	46.2	40.8	39.4	39.5	8.1	-3.1	3.7
Transpor-tation	57.6	59.8	30.3	32.0	26.1	27.0	27.3	2.1	3.9	5.5
Industry	54.2	54.6	27.4	28.0	24.6	24.7	23.9	6.9	0.8	2.3
Others	18.7	19.9	9.9	10.9	8.5	9.0	9.3	4.2	6.6	10.2
Total	**220.4**	**221.5**	**112.2**	**117.1**	**100**	**100**	**100**	**5.9**	**0.5**	**4.4**

*2012 = January –June, 2012

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Although CO_2 can be removed from the atmosphere through natural processes, increased production of anthropogenic CO_2 has exceeded natural absorption rates leading to higher CO_2 in the air. (Figure 1.2) Consequently, the over concentration of CO_2 and other GHGs in Earth's atmosphere results in disastrous global environmental consequences called “Global warming”.

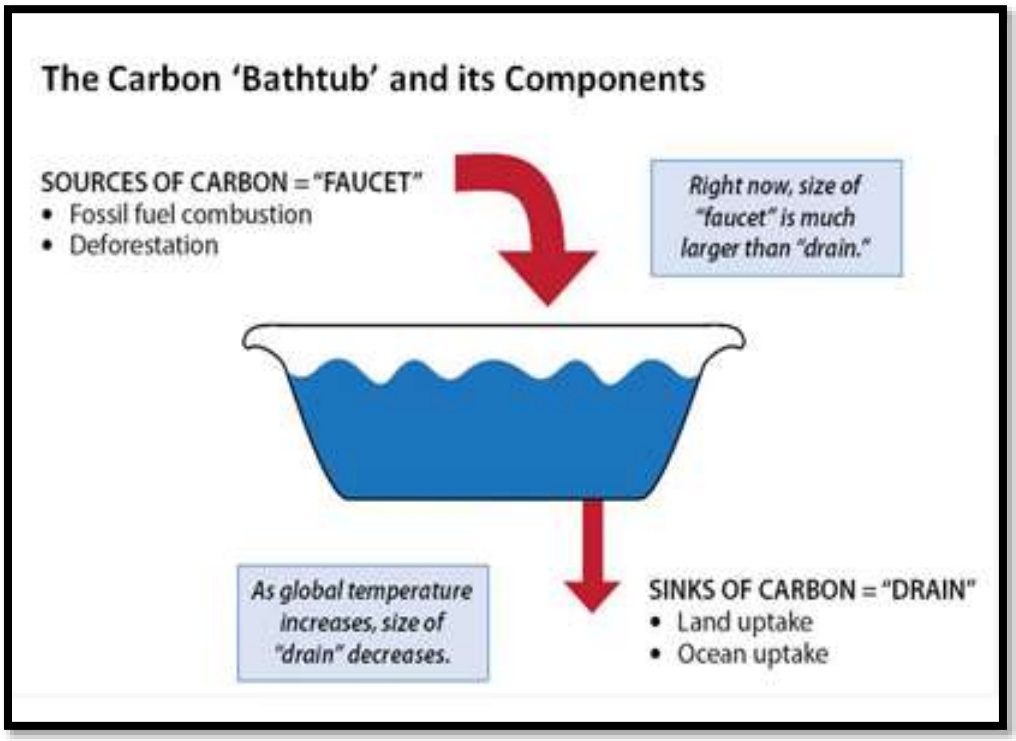

Figure 1.2 Carbon Bathtub
Source: U.S. EPA Climate Change (2012)

Apart from threatening people with global warming, petroleum-based fuel also straitens them with its price. Due to the fact that the world’s oil resources dwindle down while demand skyrockets, the price will continue to be more and more expensive.

In publication *The World Bank Group’s Response to the Global Economic Crisis* shows that there was an upward trend in the cost of fuel prior to the financial crisis, and partly in parallel with it. Unfortunately, the financial collapse and overlapping transformation from the initial U.S. financial crisis to the global economic crisis were major factors of increasing energy prices.

Referring to empirical data on E&P website, historical U.S.A. average price of gasoline and the highest diesel price in July, 2008, the prices retreated from the recent peak because of the Great Recession between late 2008 - early 2009. After that, it retraced the step and continued upward trend. Retail oil price (PTT) in Bangkok and metropolitan area between 2006 and 2012 also had the same trend. (Appendix A)

Thus, relying more on domestic fuels and importing less petroleum-based fuel will enhance the nation's energy security in the long run. Moreover, fuel price is considered being a major driver in the cost of vehicle ownership calculation. Due to an increase in

fuel price, a car fuel economy drives more consumers buying decision. (Pathumwan Nambutr, 2008)

On account of a combination of factors, such as environmental concerns and high oil prices, development of innovative energy technology has become a crucial priority for many governments and vehicle manufacturers around the world so as to relieve the problems. While government stimulates supply-push and demand-pull policies, automotive manufacturers play an important role as policy advocacy.

In addition to following the government's policies, exploiting this kind of technological innovation paves the way for manufacturers to create competitive advantages over their competitors. (Schilling, 2005)

On the one hand, vehicle manufacturers are on the forefront of developing engine and other technologies to boost fuel economy and efficiency. Pollution control technologies cannot reduce CO_2 emissions like other forms of pollution,. The only way to reduce them is to burn less fuel or to use other fuels that contain less carbon (Office of Energy Efficiency and Renewable Energy, 2012). The synthesis report to congress shows that vehicle and fuel efficiency strategies including developing and bringing to market advanced engine and transmission designs, using lighter-weight materials, improving vehicle aerodynamics, and reducing rolling resistance would bring about lower fuel use and lower emissions of transportation greenhouse gas. For example, advanced gasoline vehicles emit 8-to-30 percent of GHG less than that of a conventional vehicle. (U.S. Department of Transportation, 2010) Due to modern combustion technologies such as high precision gasoline injection, it reduces fuel consumption as well as CO_2 emission.

According to latest Fuel Economy guide (2011), 20 pounds of CO_2 is put into the atmosphere for every gallon of gasoline your vehicle burns and the average vehicle emits around 6 to 9 tons of CO_2 each year. The fewer miles per gallon vehicle burns, the lower amount of CO_2 is emitted into atmosphere. (Shown in figure 1.3)

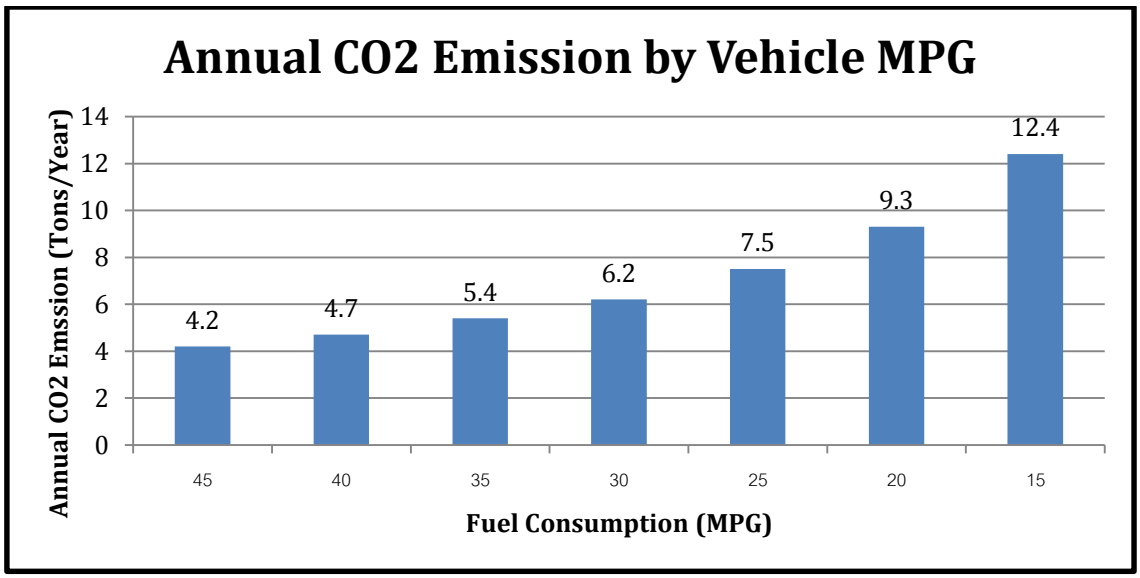

Figure 1.3 Annual CO_2 Emissions by Vehicle Miles per Gallon
Source U.S. Environment Protection Agency (2011)

On the other hand, vehicle manufacturers take great R&D efforts to innovate alternative fuel vehicles (AFVs). This refers to a vehicle that runs on a fuel other than traditional gasoline or diesel and also any methods of powering an engine that does not involve solely petroleum. According to Alternative Fuel Data Center (AFDC), designated alternative fuels include liquefied petroleum gas (LPG, also known as propane), compressed natural gas (CNG), ethanol, biodiesel, electricity and hydrogen.

In case of Thailand, to reduce the number of import foreign oil supplies and GHG emissions, the Ministry of Energy announced the policy to pursue the country own alternative sources of energy in 2007. A considerable part of this policy has been on promoting the use of eco car and innovative electrified vehicles. (Shown in table 1.2)

Table 1.2 Automotive Excise Taxes

Type	Condition & Excise Tax			
Passenger Car	< 2,000 cc & < 220 H.P. : 30%	2,000 - 2,500 cc & < 220 H.P. : 35%	2,500 - 3,000 cc & < 220 H.P. : 40%	> 3,000 cc or > 220 H.P. : 50%
E20 Compatible Car	< 2,000 cc & < 220 H.P. : 25%	2,000 - 2,500 cc & < 220 H.P. : 30%	2,500 - 3,000 cc & < 220 H.P. : 35%	> 3,000 cc or > 220 H.P. : 50%
E85 Compatible Car	1,780 - 2,000 cc & < 220 H.P. : 22%	2,000-2,500 cc & < 220 H.P. : 27%	2,500-3,000 cc & < 220 H.P. : 32%	
Passenger Pickup Vehicle (PPV)	< 3,250 cc : 20%		> 3,250 cc : 50%	
Single Cab Pickup	< 3,250 cc : 3%		> 3,250 cc : 50%	
Double Cap Pickup	< 3,250 cc :12%		> 3,250 cc : 50%	
Natural Gas	20%			
NGV Retrofit	< 2,000 cc & < 220 H.P. : 30%	2,000 - 2,500 cc & < 220 H.P. : 35%	2,500 - 3,000 cc & < 220 H.P. : 40%	> 3,000 cc or > 220 H.P. : 50%
Eco-Car (Gasoline)	≤ 1,300 cc : 17%			
Eco-Car (Diesel)	≤ 1,400 cc : 17%			
Hybrid Vehicle	< 3,000 cc : 10%		> 3,000 cc :50%	
Electronic Powered	10%			
Fuel Cell Powered	10%			

Source: Excise Department, Ministry of Finance (2012)

Among innovative electrified vehicles, this research chooses to focus only on Hybrid Electric Vehicle (HEV) and neglect Fuel Cell Vehicle (FCV), Plug-in Hybrid Electric Vehicles (PHEV) and BEV (Battery Electric Vehicle) due to the fact that PHEV and BEV in Thailand are not commercialized yet and get stuck in the unavoidable barrier. It is the lack of a widespread refueling infrastructure. This barrier is vicious cycle, and hard to overcome in the near future. In 2002, the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) describes about this in *Alternative Fuel Vehicles* publication. *"potential buyers might hesitate to purchase AFVs in large*

volume until commercial refueling stations are readily available. At the same time, station owners might hesitate to invest in the refueling infrastructure until there are enough AFVs to make it a good investment." Moreover, Michalek and his co-writers (2011) estimate life-cycle air emissions and oil displacement benefits of conventional vehicle (internal combustion) and other electrified vehicles relative to PHEVs. In addition, the result showed that in base case and pessimistic case (low gas price and electricity generated by coal fired power plant), PHEV and BEV could be more responsible for life-cycle emission externality damages and oil premium costs (except PHEV 20; base case). Also, they have more than net present value (NPV) of lifetime private ownership cost over the HEV.

Thus, HEV becomes interesting alternatives to conventional engine vehicle because of higher fuel economy by combining propulsion systems between a conventional engine and a rechargeable battery to provide motive power. The increased fuel economy of hybrids makes HEVs more attractive to consumers.

Nowadays, there are many hybrid models officially marketed in Thailand as shown in Table 1.3.

Table 1.3 List of Officially Marketing Hybrid Car in Thailand

Model	Engine (litres) g–gasoline d-diesel	Official Debut in Thailand	Price (Baht)		
			Normal	Standard Grade	Top Option Grade
Toyota Camry Hybrid (XV40)	2.4 g	2008	N/A	1,599,000	1,779,000
Toyota Camry Hybrid (XV50)	2.5 g	3/2012	1,499,000 (2.5 G A/T)	1,649,000	1,869,000
Toyota Prius Generation 3	1.8 g	11/2010	NEM	1,199,000	1,369,000
Alphard Hybrid	2.4 g	2012	3,339,000 (2.4 V)	3,459,000	
Toyota Prius C	1.5 g	3/2012	NEM	1,390,000	
Honda Jazz Hybrid	1.3 g	7/2012	NEM	768,000	
Honda Civic Hybrid	1.5 g	3/2013	828,000 (1.8 S A/T)	1,035,000	1,095,000
Honda CR-Z	1.5 g	8/2012	NEM	1,975,000	
Lexus CT 200h	1.8 g	2/2011	NEM	2,215,000	2,920,000
Lexus RX450h Generation 2	3.5 g	2012	NEM	6,990,000	
Lexus GS450h	3.5 g	3/2012	NEM	7,790,000	
Lexus LS600h	5.0 g	N/A	NEM	13,580,000	
Benz E300 Bluetec hybrid	2.1d	3/2013	NEM	4,199,000	4,499,000

NEM = No Equivalent Model, N/A = Not Available

Table 1.3 List of Officially Marketing Hybrid Car in Thailand (Continued)

Model	Engine (litres) g–gasoline d-diesel	Official Debut in Thailand	Price (Baht)		
			Normal	Standard Grade	Top Option Grade
BMW Active Hybrid 3	3.0 g	3/2013	NEM	4,199,000	4,499,000
BMW Active Hybrid 5	3.0 g	2012	NEM	5,399,000	5,599,000
BMW Active Hybrid 7	3.0 g	3/2013	NEM	8,299,000	8,999,000
Porche Cayenne S Hybrid	3.0 g	03/2012 (AAS)	NEM	7,900,000	
Porche Panamera S Hybrid	3.0 g	03/2012 (AAS)	NEM	9,600,000	

NEM = No Equivalent Model, N/A = Not Available

While HEV uses new technology of combining propulsion systems to increase fuel economy, eco car uses another method by downsizing engine. According to UNECE standard, there are 4 criteria eco car must pass and the first one is that vehicle that can be eco car have to consume fuel less than 5 liters per 100 kilometers under combine mode testing UNECE Reg. 101 Rev. 1. Moreover, eco car must emit CO_2 less than 120 grams/ kilometers and pass the UNECE crashworthiness standards R94 (protection of the occupants in the event of a frontal collision) and R95 (protection of the occupants in the event of a lateral collision). Nowadays, there are 6 models of eco cars passing these criteria and officially introduced. (Table 1.4)

Table 1.4 Lists of Officially Marketing Eco Cars in Thailand

Brand	Model	Type	Engine Size	Price (Baht)
Nissan	March	Hatchback	1.2 L	380,000 – 563,800
	Almera	Sedan	1.2 L	429,000 – 599,000
Suzuki	Swift	Hatchback	1.25 L	429,000 - 559,000
Mitsubishi	Mirage	Hatchback	1.2 L	380,000 – 546,000
Honda	Brio	Hatchback	1.2 L	433,500 – 508,500
	Brio Amaze	Sedan	1.2 L	454,000 – 521,000

Special Criteria: Additional to aforementioned criteria, if and only if the car is domestic manufactured, it is classified as “eco car”.

Although HEV and eco car are fuel-economy vehicle, the natures of these two types of vehicle are extremely different. Thus, it is interesting to explore the diffusion pattern of these 2 innovations.

1.2 Objectives of the Study

1) To explore the pattern of diffusion between HEV and eco car in Thailand
2) To suggest government policies to encourage HEV and eco car adoption

1.3 Significance of the Study

1) Saturation level and curve of adoption are alternative guides for helping Thai government make policy and regulation to promote HEV and eco car adoption as well as help vehicle manufacturers make time-plan for new product launching.

2) Suggested policies in this research could be used to promote rate of HEV and eco car adoption

3) The diffusion pattern of HEV could be used in future comparative study in diffusion of more efficient FCV using less fossil fuel and significantly emitting lower GHGs than a comparable HEV such as PHEV. (ERPI, 2007)

1.4 Scope and Limitation of the Study

1) According to Rogers (2003), there are 5 variables determining the rate of adoption of innovations. This research will focus only on communication channels and perceived attributes of innovations.

2) The research will use Bass diffusion model to find out diffusion patterns of HEV and eco car adoption. In case of HEV, this part will use secondary data, which is the number of new registered light duty vehicles type 1 (classified by type of fuel usage) obtained from Transport Statistics Sub-Division, Planning Division and Department of Land Transport. The available data are published every transitional quarter and cover the fiscal year 2007 – 2013 (January 2007 - December 2012).

3) In case of eco car, this research will use the number of new registered vehicles with engine size less than 1,300 cc as a proxy of eco car sales due to limitation of data. The available data are recorded monthly during April 2011 and March 2013 and classified by brand and size of engine.

4) This research focuses only on demand pull policies.

1.5 Definition of Terms

Hybrid Electric Vehicle (HEV): light duty vehicle with high fuel economy by combining propulsion systems between a conventional engine and a rechargeable battery to provide motive power.

Conventional Vehicle (CV): vehicle with internal combustion engine

Alternative Fuel Vehicle (AFV): vehicle that runs on a fuel other than "traditional" petroleum fuels (gasoline or diesel), or uses any technology of powering an engine that does not involve solely petroleum

Eco Car: domestically manufactured vehicle with engine size under 1,300 cc for gasoline engine or 1,400 cc for diesel engine which has fuel consumption less than 20 kilometers/liter, emits CO_2 less than 120 grams/ kilometer and also pass these UNECE crashworthiness standards R94 (protection of the occupants in the event of a frontal collision) and R95 (protection of the occupants in the event of a lateral collision).

Except in the analysis part: The definition is defined the vehicle with engine size under 1,300 cc. under 4 brands as follow.

1) Nissan : as proxies of Nissan March and Nissan Almera
2) Honda : as proxies of Honda Brio and Honda Brio Amaze
3) Mitsubishi : as proxy of Mitsubishi Mirage

4) Suzuki : as proxy of Suzuki Swift (1.25L)