

MASTER THESIS

Course code: **EN310E**

Candidate name: **Saiful Hasan**

Impact on crude oil demand by electric vehicles in China
- Adopting measures similar to Norwegian EV policy

Date: **20. 05.2017**

Total number of pages: **122**

Preface

This thesis concludes my study of Master of Science in Energy Management at Nord University. Writing this thesis has been a learning process for me and has given me deep insight about scientific research work. Writing this thesis also enriched my knowledge about different aspects of electric vehicle industry and their direct impacts on energy market.

Over the last two years we were taught the ins and outs of energy industry. The recent oil crisis encouraged me to think deeply about the possibilities that can impact the energy market especially the oil industry largely. Such thought has led me to choose my current thesis topic. The recent hype about the electric vehicle is considered as one of the concerns for energy industry. To me, studying the insight of electric vehicle was very interesting and moreover, being able to connect it with crude oil demand was very exciting for me. My supervisor also gave me helpful suggestions to narrow down the aspects and to make a concrete research topic.

I would like to give my sincere thanks to my supervisor, Professor Terje Andreas Mathisen for his excellent guidance and support during my thesis writing. His precious advices have guided me to shape and construct my thoughts and writing materials. I would like to thank our program coordinator Elena Dybtsyna as well. Last but not least, I would like to thank my family for their continuous support during my studies.

Bodø 19th May, 2017

Saiful Hasan

Abstract

As a result of consistent growth in global population, economic development, and urbanization, the transport sector, particularly the road transport is facing rapid growing demand which leads to severe environmental and energy challenges, especially for big emerging economies, e.g. China and India. Leading energy consuming countries are now more concern about establishing energy security and simultaneously emphasizing on reducing environmental pollutions. Countries are considering promoting electric vehicles (EVs) as one of the prominent strategy with the expectation that it will mitigate their energy and environmental challenges to greater extent and in addition, EVs is considered as a platform of enormous prospects for automobile manufacturing countries. The world's largest automotive market for both ICE vehicles and electric vehicles, China is consistently investing massively to promote EVs throughout the country though both previous studies and this research analysis suggest that yet China needs to upgrade their EV policy measures to accomplish their set targets. On the other side, Norway utilizing its generous EV policy measures sets example for other countries by pursuing highest EV market share of all new cars for last few years. With both descriptive and quantitative analysis this research paper concludes that by adopting similar Norwegian EV policy measures China can lift up their EV market share largely. This research paper rigorously investigates ins and outs of both China's and Norwegian EV policy measures, and establishes a general EV market share (EVMS) model to measure the EV market share. EVMS model can be used by the policy makers to control the EV market shares to some extent by imposing different necessary EV policy measures and this model can be implemented by any country. Moreover, being both the largest and rapidly growing automobile market, it is certain that electric vehicles have intense impact on crude oil demand of China. This research paper quantified that the magnitude of changes in crude oil demand by embedding similar Norwegian electric vehicle policy measures in the electric vehicle market of China is so significant that electric passenger cars stocks alone can cut off almost 1 million barrels per day (or even more) of oil demand. In addition, after briefly analyzing the rest of the world's aspects it can be assert that if the global EV market adopts enhanced EV policy measures and continues to increase briskly then the global crude oil demand will reduce severely that can lead another oil gluts in near future, even within 2030. The findings by this study are of interest to EV policy makers from any countries, EV manufacturers and oil industry. Further research should include quantifying two important policy measures (communication process and availability of different electric vehicle brand) that have tendency to influence the EV market share greatly.

List of Acronyms

EVI = Electric vehicles initiatives

EV = Electric Vehicle, (in this research paper, by EV only the electric cars is described, not any other types of vehicles)

NEV = New Energy Vehicle (new energy vehicles, alternative fuel vehicles, electric vehicles all terms are interchangeable and hence, in this research, often for generalization only electric vehicle term is used instead of new energy vehicle)

ICE = Internal Combustion Engine

BEV = Battery Electric Vehicle

PHEV = Plug-in Hybrid Electric Vehicle

HEV = Hybrid Electric Vehicle

FCEV = Fuel Cell Electric Vehicle

GHG = Greenhouse gas (Includes Carbon dioxide CO₂, Methane (CH₄), Nitrous Oxide (N₂O), Fluorinated gases), *Source:* (EPA, 2017)

EVSE = Electric Vehicle Supply Equipment (electric charging infrastructures)

HOV Lane = Heavy Occupancy Vehicle Lane

VAT = Value Added Tax

NPV = Net Present Value

IEA = International Energy Association

OECD = Organization for Economic Co-operation and Development

OPEC = Organization for Economic Co-operation and Development

YTD = Year to date

OEM = Original Equipment Manufacturers

mb/d = million barrel per day

CAA = Canadian Automobile association

Table of contents

Chapter 1: Introduction	1
1.1 Background	1
1.2 Problem Statement	3
1.3 Purpose of the research	3
1.4 Scope and Limitations.....	4
1.5 Structure of the thesis.....	4
Chapter 2: Fields of study	6
2.1 Electric Vehicle (EV).....	6
2.2 Norwegian Electric Vehicle (EV) policy	8
2.3 New Energy Vehicle (NEV) policy of China	11
2.4 Transportation and crude oil demand.....	14
2.5 Comparison between Norwegian EV policy and New Energy Vehicle (NEV) Policy of China.....	17
2.5.1 EV purchase incentives	18
2.5.2. EV use incentives.....	20
2.5.3 Waivers on access restrictions	21
2.5.4. Supporting policy measures	21
2.5.5 Summary of comparison of the policy measures	26
Chapter 3: Theoretical Framework	28
3.1 Diffusion of Innovations	29
3.1.1 Innovativeness and Adopter Categories.....	29
3.1.2 The Innovation-decision process	30
3.2 Factors to influence transport demand	33
3.3 The economy of large-scale energy vehicle transition.....	34
3.4 Modeling for EV Market Share (EVMS model).....	37
3.5 Statistical models	40
3.5.1 Forecasting Model.....	40
3.5.2 Measurement of magnitude of the consequence of the crude oil demand	42
Chapter 4: Methodology	44
4.1 Research philosophy	44
4.1.1 Positivism.....	45
4.1.2 Linking Ontology, Epistemology and Methodology	45
4.1.3 Critical Realism	46
4.1.4 Scientific Realism (Philosophy for quantitative research).....	47
4.1.5 Neoclassic Research Paradigm	48
4.2 Philosophical positioning of the research	49

4.3 Research Process.....	50
4.4 Data collection	51
4.5 Autoregressive Integrated Moving Average (ARIMA) model	53
4.6 Regression Analysis.....	55
4.7 Reliability and Validity.....	56
Chapter 5: Empirical data	59
5.1 The magnitude of automotive market in China.....	59
5.2 The prospect of automotive market in China.....	61
5.3 Electric vehicle market differences between Norway and China	62
5.4 Impact of individual policy measures on EV market share	65
5.5 Parameter for fuel consumption and crude oil demand	69
Chapter 6: Analysis and Discussion.....	71
6.1 Why does China need more incentives?	71
6.2 Does China need to invest more on supporting EV policy measures?.....	74
6.2.1 Charging Infrastructures or EVSE	74
6.2.2 Communication process	75
6.2.3 Availability of different EV brands	76
6.3 The possible EV market share changes by adopting Norway’s EV policy.....	76
6.4 The consequences for Crude oil demand in China due to EVs.....	80
6.5 Global scenarios.....	89
Chapter 7: Conclusion.....	94
7.1 Conclusion	94
7.1.1 Summary	94
7.1.2 Implications.....	96
7.2 Future research scope.....	97
Bibliography	99
Appendices.....	107
Appendix 1: Tables and Figures	107

List of Tables

Table 2.1 Key differences among different types of electric vehicles	6
Table 2.2 Top manufacturer based on world-wide sales, YTD (Nov'15)	7
Table 2.3 The five phases of BEV development in Norway (up to 2014)	10-11
Table 2.4 NEV framework development up to 2015	14
Table 2.5 Differences between Norwegian EV policy and Chinese New Energy Policy	17
Table 2.6 Tax scheme differences between Norway and China	18
Table 2.7 Calculated average values per year of different local incentives per car and for total fleet in Norway total fleet in Norway = 25 000 EV's in April 2014	20
Table 2.8 Summary of comparison of EV policy measures	26-27
Table 4.1 Four different Ontologies	44
Table 4.2 Methodology implications of different epistemologies	46
Table 4.3 List of key sources for key data used for this research	52
Table 4.4 Source of Coefficient or parameters of different variables	53
Table 5.1 How much China accounts for global conventional passenger car sale	60
Table 5.2 Avg. scores for the selective policy measures on their effectiveness, efficiency, feasibility	66
Table 5.3 Correlation of individual incentives with EV market share (%)	66
Table 5.4 Contribution of individual incentives to BEV market share (%), (in Norway)	67
Table 5.5 Selective previous studies evaluating the importance of consumer awareness	68-69
Table 6.1 Calculation break-down of the impact of charging infrastructures, I, in China EV market share	77
Table 6.2 Calculation break-down of the Impact of purchase incentives, P, in China EV market share	78
Table 6.3 The contribution of all necessary EV policy measures to the market share, In China	79
Table 6.5 Forecast of China EV market share of all new cars, 2017-2022	82
Table 6.6 Forecast of numbers of new EVs sales for each years based on different scenarios	83
Table 6.7 Possible crude oil demand (mb/d) reduction if EV stock % reaches at difference point against passenger car stocks in 2035, China	88
Table 6.8 Possible market share changes of selected countries after the impact of building different number of charging infrastructures	89

Table 6.9 SPSS results for regression analysis	90
Table 6.10 Projection of fall of crude oil demand if listed countries managed to meet their EV stock target in 2020	91

List of Figures

Figure 2.1 Projection of global electric vehicle sales	8
Figure 2.2 EV Market share development in Norway	9
Figure 2.3 Electric vehicle incentives and approximate EV shares of new vehicles in selected Chinese cities (through September, 2015)	13
Figure 2.4 Global crude oil consumption in 2012 by sector	15
Figure 2.5 Liquids fuels demand by sector	16
Figure 2.6 Vehicle fleet growth in OECD and Non-OECD countries	16
Figure 2.7 Difference between price of ICEs and EVs after national subsidies deductions, in China	19
Figure 2.8 Growth of installing fast charging stations over years, 2011-15	23
Figure 2.9 EV Models availability in different countries, 2012-2015	25
Figure 2.10 Percentage of EV sale increase compared to previous years	26
Figure 3.1 Innovation adopter categories	30
Figure 3.2 Innovation-decision process with 5 stages	31
Figure 3.3 Simple demand curve	33
Figure 3.4 Determination of an efficient quantity of vehicle sales in year t and an efficient subsidy	36
Figure 3.5 How Electric vehicle impacts the crude oil demand	43
Figure 4.1 Differences (lagged by one period) between years of the data set of China's conventional passenger cars, 2005-2015	54
Figure 4.2 Autocorrelation analysis between the differences (lagged by one period) of data set China's conventional passenger cars, 2015-2015	55
Figure 5.1 Sales growth (passenger cars) comparison between china and rest of the world	59
Figure 5.2 BEV sales in China and rest of the world	60
Figure 5.3 Market share (%) development of EVs (BEVs and PHEVs) in Norway and China, 2008-2015	62

Figure 5.4 Evolution of BEV shares against total passenger cars in Norway and China, 2008-2015	63
Figure 5.5 EV (BEVs and PHEVs) stock percentage against total passenger car stock, 2010-2015	64
Figure 5.6 Passenger cars and EVs per 1000 inhabitants in Norway and China, 2010-2015	65
Figures 6.1 Technology adoption curve including select electric vehicle markets (this graph need edit)	72
Figure 6.2 Effect of alternative cars price on electric vehicle's demand shift	73
Figure 6.3 Possible way to make the EV purchase price more competitive	73
Figure 6.4 How the generalized cost of electric transport can be lowered	74
Figure 6.5 Forecast of number of new passenger car, for each year from 2017-2035	81
Figure 6.6 Forecast of EV market shares of all new cars by adopting Norwegian EV policy with different charging infrastructure scenarios, China (2017-2022)	82
Figure 6.7 Forecast of reduction in fuel consumption based on new EV sales for each year 2017-2022, China	83
Figure 6.8 Forecast of reduction in crude oil demand based on new EV sales for each year 2017-2022, China	84
Figure 6.9 Forecast of reduction in crude oil demand based on EV stocks for each year 2017-2022, China	86
Figure 6.10 Prediction of the next oil crisis based on EV stocks globally	93

Chapter 1: Introduction

1.1 Background

Electrification of vehicles is considered as an important measure to lessen greenhouse gas (GHG) emission from transport sector, to minimize the reliance on petroleum, especially for net petroleum importing countries since electric vehicles (EVs) are more energy efficient than the conventional vehicles (ICE Vehicles), and to mitigate other environmental impacts, e.g. reduction in traffic noise. The share of global oil consumption by transport sector increased from 42.5% in 1973 to 61.7% in 2009 and transport sector, especially road transport is responsible for 23% of the global CO₂ emission in 2009 (IEA, 2011). The growth in global vehicle fleet leads towards two key global problems: growth in energy demand and increasing GHG emission. While growth in energy demand will add pressure on global energy system, GHG emission will contribute to climate change negatively. Recently, electrification of vehicles appears as promising pathway to handle the challenges. For the accelerated development and deployment of electric vehicles (EVs) globally a policy dialogue named electric vehicles initiatives (EVI) is established. EVI aims to facilitate deployment of 20 million passenger vehicles (including plug-in hybrid vehicles and fuel cell electric vehicles) globally by 2020 (IEA, 2016). IEA has estimated that electric vehicles will represent 35% of new vehicles sales by 2035 and that will limit the climate change to less than 2 degree Celsius. According to Economist (2017), the global market share of EV is still well below 1% while Morgan Stanley and Exane BNP Paribas are expecting 7% and more than 11% of global EV market share respectively by 2025. Mark Fields, President and CEO of Ford, announced that “the era of the electric vehicles is drawing” (Economist, 2017: p 53). Mark Fields expects that within 15 years the number of models of EVs will exceed pure internal combustion engine (ICE) vehicles (Economist, 2017). On the contrary, OPEC states that EVs will be only around 1% of cars in 2040. Ryan Lance, CEO of ConocoPhillips believes that “EVs will not have any material impact for another 50 years-probably not in lifetime” (Randall, 2016).

In Norway, however, the EV market is booming for last few years and in 2016, EV (BEVs and PHEVs) market share accounts for 29% of all new vehicle sales (Economist, 2017). Norway also has the largest number of EVs per capita (Fearnley et al., 2015). The success in EV market is the result of Norwegian government’s execution of structured operational planning and obviously national-wide substantial EV policy measures. Moreover, as per 2015

data, Norway has produced 98% of its electricity by renewable energy (Norwegian Water Resources and Energy Directorate, 2016). Thus, Norway also has answer for the critics, who bearing in mind the fuel type used for electricity production, question if electric vehicles are really clean drive. Julian Marshall, an associate professor of environmental engineering at the University of Minnesota, said “If there’s anyone in the world who should be using electric vehicles, it is Norway. That’s a place with clean energy” (Jolly, 2015). When it comes to electric vehicle adoption, Elon Musk, Tesla and SpaceX CEO, noted Norway as world leader “Norway is a world leader when it comes to electric mobility. Your political incentives represent a great catalyst for the fantastic EV adoption, and you have fought for sustainable transport for more than 20 years. Not to forget renewable energy” (Ayre, 2016). Christina Bu, Secretary General of Norwegian EV association, is also confident about their EV policy measures and inspires other countries to implement similar measures saying “Norway inspires other countries to implement similar measures, and we show the international automotive industry how to create consumer demand for electric cars. We get ever more proof supporting this notion” (Kane, 2016)

In China, passenger vehicles have increased by 8 times during the last two decades. Particularly, the rapid growth of private vehicles has resulted in continuing growth in China’s oil demand and it is predicted that the annual oil demand of China’s road vehicles will reach 363 million tons by 2030 (Zhang et al., 2011). Autofacts (2016) argued that the automotive emissions (GHG emissions) have been the primary target behind the extended focus on mass adoption of new energy vehicles (NEVs). In China, still a great percentage of energy production (64%) is coal-based but it believes that high energy efficient electric vehicles as well as introduction of coal-based fuels coupled with Carbon Dioxide Capture and Storage (CCS) can be considered as reliable option for sustainable transportation energy system, which can minimize the fossil fuel demand by 21.58% and lessen GHG emission by 15.61% in 2050 (Zhang et al., 2011).

In 2015, China was the largest market for EVs with around 200,000 new registrations (IEA, 2016). China government invests in NEV industry by tax reduction, research and development, infrastructure building and supply subsidies. Up to mid-year 2016, total investment in NEV industry by China government has reached about \$7.2 billion (An, 2016). Furthermore, in China, some significant investments are taking place including, \$ 20 billion RMB investment by LeEco for building ‘automotive ecological town’, \$11 billion RMB investment by Build Your Dream (BYD) to build a 10GWh battery factory. The recent

growth in EV market and investments reflects China's enthusiasm and capitalization capability for mass adoption of EVs. (Zhang et al., 2011)

1.2 Problem Statement

Electric vehicles (EVs) or New Energy Vehicles (NEVs) or Alternative Fuel Vehicles (AFVs), regardless of what term is used, are playing a phenomenal role in reviving the global automobile industry. Nevertheless, the demand for EVs is yet comparatively small in size but the growth is significant for last few years. Along with large investments in R&D and developing cost-efficient technologies, mass adoption of EVs requires effective and efficient EV policy measures. On the other side, EVs have impact on fuel consumption which influences the crude oil demand. On this basis I have chosen the following research question:

What would be the magnitude of changes in the crude oil demand by adopting similar Norwegian EV Policy measures? - Evidence from China

This research analyzes the differences between the Norwegian EV policy and China's New Energy Vehicle (NEV) Policy, which eventually leads to the analysis and discussion if China can boost the EV market share by adopting similar Norwegian EV policy measures. In later analysis, this research estimates the consequences for crude oil demand in China due to mass adoption of EVs. The changes in global crude oil demand due to EVs have been also included briefly at the end of the thesis.

1.3 Purpose of the research

Even though Norwegian EV policy is appreciated globally for its influential role in Norwegian car market, to my knowledge until recently little attention has been paid to examine the possible changes that can happen in EV market share by adopting similar Norwegian EV policy measures by any other countries. There are researches measuring the effectiveness of different policy measures and social factors, but little attention has been paid so far, to my knowledge, to produce a general model or framework combining all necessary EV policy measures to increase the EV market share efficiently and effectively. The discussion and analysis of EV policies of this thesis can provide the EV policy makers or countries, particularly China, some leads to make effective and efficient EV policy measures. I believe the model for EV market share, EVMS, can help any country to increase their EV market share by adopting different effective policy measures. Moreover, there is also global debate on the magnitude of impacts caused by EVs on crude oil demands; automobile industry and petroleum industry have different anticipations. Most importantly, the results of

this research analysis illustrate how EVs can reduce the petroleum dependency and how EVs can become a crucial factor for crude oil industry.

1.4 Scope and Limitations

This research seeks to investigate the potential impact EVs may have on crude oil demand and thus the scope of this research is solely based on EVs, without considering the potential impact of other alternative modes of transport. Moreover, this research analysis only concentrated on passenger cars, excluding other type of vehicles, e.g. buses, trucks.

If we consider from the production of EVs to how the electricity is generated (fuel type used in generating electricity), then EVs may not be fully clean or green drives for some countries, e.g. in China still main source of energy production is coal. But the research problem of this paper focuses only on the impact of EVs on crude oil demand and therefore, having acknowledged the environmental matters, I have limited this research analysis only to the changes in crude oil demand by EVs

As already the research question suggests, this thesis has mostly described and conducted the analysis based on two countries' perspectives; EV policy measures, EV markets of Norway and China. But in few cases, I have also briefly described possible scenarios for other countries as well, e.g., the modeling for EV Market Share (EVMS can be considered by other countries as well) and the changes in global crude oil demand due to EV adoptions.

1.5 Structure of the thesis

This research paper is divided into seven chapters:

1. Introduction:

It includes brief introduction of the topic of the research problem, research question, scope and limitation of the research paper.

2. Fields of Study:

This chapter includes brief discussion of the research areas covered by the research question and establishment of basis for later chapters.

3. Theoretical Framework:

This chapter includes relevant theoretical framework to support the analysis and establishment of necessary modeling for the analysis purpose.

4. Methodology:

This chapter explains the philosophical positioning of the research as well as the research approach and methodical choices has been in this research. The validity and reliability of this research is also included in this chapter.

5. **Empirical data:**

This chapter presents empirical data from relevant previous studies, journal publications, archives to conduct the analysis in order to answer the research question.

6. **Analysis and Discussion:**

This chapter combines the theoretical literature and empirical data together to conduct the analysis in order to answer research question and includes a brief discussion as well.

7. **Conclusion and Recommendation:**

This chapter concludes the thesis with summary, implementation and explaining scopes for further research.

Chapter 2: Fields of study

This chapter starts with brief description on electric vehicles (EVs), Norwegian EV policy measures and NEV policy of China. Thereafter, it illustrates the significance of transport sector in crude oil industry. In later part of this chapter, comprehensive comparison between these two policies has been made. This chapter institutes the platforms for later chapters.

2.1 Electric Vehicle (EV)

Electric Vehicles are considered as one of the imperative solutions for climate change and petroleum dependences. Electric Vehicles (EVs) includes the Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Fuel-Cell Electric Vehicles (FCEVs), though sometimes the term 'EV's are referred to as BEVs (U.S. Department of Energy). These vehicle-types are named based on how these vehicles are powered for driving. Table 2.1 states the key differences among all the electric vehicle types.

Table 2.1

Key differences among different types of electric vehicles; Source: (CAA, 2017)

Battery Electric Vehicle	BEV runs entirely on a battery and electric drive train, without an internal combustion engine (ICE)
Plug-in Hybrid Electric Vehicle	PHEV runs mostly on a battery. PHEV is also equipped with an internal combustion engine (ICE), running on gasoline or diesel fuel, that can recharge the battery and/or to replace the electric drive train when the battery is low and more power is required.
Hybrid Electric Vehicle	HEV has two complementary drive systems - a gasoline engine and fuel tank, and an electric motor, battery and controls. The engine and the motor can simultaneously turn the transmission, which powers the wheels. Unlike BEVs and PHEVs, HEVs cannot be recharged from the power grid; for energy it has to solely rely on gasoline.
Fuel-Cell Electric Vehicle	FCEV creates electricity from hydrogen and oxygen, instead of storing and releasing energy like a battery

Electric vehicles can be powered by gasoline and/or electricity grid and especially BEVs, FCEVs, PHEVs reduce environmental impact of driving, such as reduces the greenhouse gas (GHS) emission. Therefore, Axsen and Kurani (2012), based on Rogers' innovation theory, explains that from technology-focused perspective electric vehicles are technological

innovation due to the physical and functional differences from conventional vehicles. Electric vehicle can be considered as functional innovation as they reduce fuel cost and improve driving experience for drivers. Axsen and Kurani (2012) conceptualized the potential benefits of electric vehicles according to two dimensions: functional-symbolic and private-societal and urged that those electric vehicles may also be assessed as innovation as electric vehicles benefit society, e.g. reduce environmental pollutions. Axsen and Kurani (2012) elaborately explains that electric vehicles provide public reduction in air pollution, greenhouse gas emission, traffic noise pollution, and oil dependence (societal-functional benefits) in addition to the private benefits and influences others to think of and act on such issue which are considered as societal-symbolic benefits (Axsen and Kurani, 2012).

The idea of electric vehicle is not new; electric cars were introduced more than 100 years ago. The recent era of electric vehicle has arrived after a series of breakthroughs – from battery to electric motor. Therefore, it is rather difficult to pinpoint the invention of electric cars to one inventor or country (Matulka, 2014). According to Business Wire (2015), currently top electric vehicle manufacturers in the world are BYD, Nissan, Tesla, Mitsubishi, VW, BMW, Renault, Ford (table. 2,2).

Table 2.2
Top manufacturer based on world-wide sales, Years to date (YTD) (Nov'15)

Ranking	Manufacturer	Sales units (YTD;Nov'15)
1	BYD	50,801
2	Nissan	44,553
3	Tesla	42,091
4	Mitsubishi	40,667
5	Volkswagen	33121
6	BMW	29,018
7	Renault	22,986
8	Kandi	21,554
9	Zotye	20,219
10	Ford	18,966

Source: (Business Wire, 2015) and (Pontes, 2015)

A Bloomberg New Energy Finance report suggests that the sale of electric vehicles will increase beyond expectation and will hit 41 million by 2040 (fig. 2.1) which will represent 35% of new light duty vehicle sales. The report also highlights that by the year 2022, electric

vehicles will cost the same as their gasoline-driven equivalents and that will be the point from where the electric vehicle sales will liftoff.

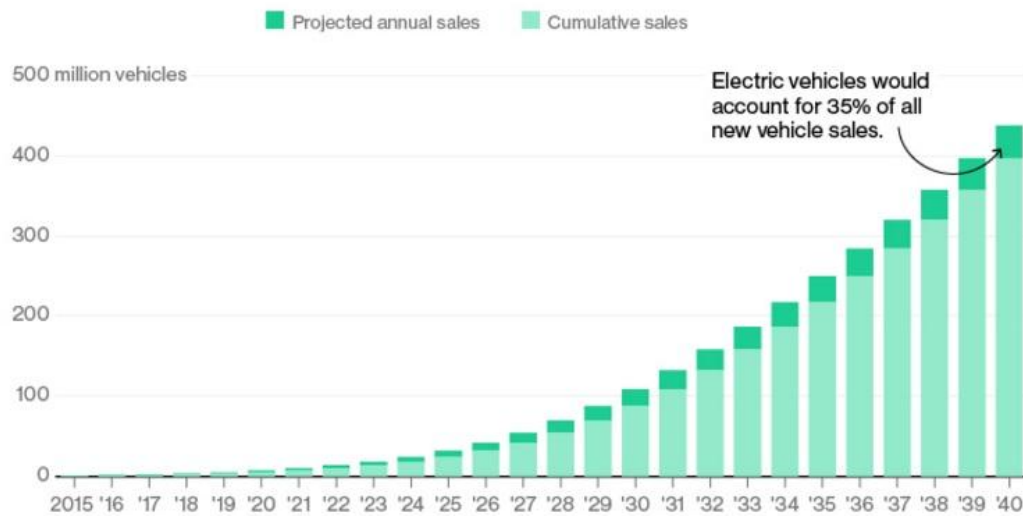


Figure 2.1: Projection of global electric vehicle sales; Source: (Randall, 2016)

2.2 Norwegian Electric Vehicle (EV) policy

In response to the climate change, electrification of vehicles is one of the important measures to reduce the environmental impact caused by transports. Norwegian EV policy is established on the widespread belief that electric vehicles (EVs) are more environmentally friendly than vehicles powered by fossil fuels, gasoline and diesel fuel (Holtsmark & Skonhoft, 2014). Norway is leading the way of transition to electric mobility. In 2016, the market share of electric vehicles in Norway was 29% (Norsk ebilforening, 2017) of all new cars, which represents the highest market share of EVs in any country in 2016. In 2014 and 2015 strong increases in sale of electric vehicles took place in Norway and in 2015 year-on-year sales growth for electric vehicles exceeded 75% (IEA, 2016). Norway's continuous success in EV market is the result of its developed substantial package of incentives to promote zero emission cars. Holtsmark & Skonhoft (2014) explains that the high number of EVs in Norway is the ultimate result of the generous EV policy measures that consistently motivating people to purchase and use EVs. Globally electric vehicle fleet develops more slowly compared to the rapid changes observed in Norway. Figenbaum et al., (2015) mentioned Norway as a forerunning country within electro mobility. The last few years, especially from 2011, the growth rate of electric vehicles (EVs) in Norwegian market has been formidable. The market share development of battery electric cars (BEVs) and plug-in hybrid electric cars (PHEVs) in Norway are demonstrated by figure 2.2. The market shares in figure 2.2 represents the market shares of Battery electric cars (BEVs) and Plug-in hybrid

electric cars (PHEVs) against the total new passenger car sales in respective years, e.g., in 2015, around 28,000 battery electric cars were sold (151,000 new passenger vehicles) which resulted 18% of the market share and 8000 plug-in hybrid electric cars resulted 5% of market share.

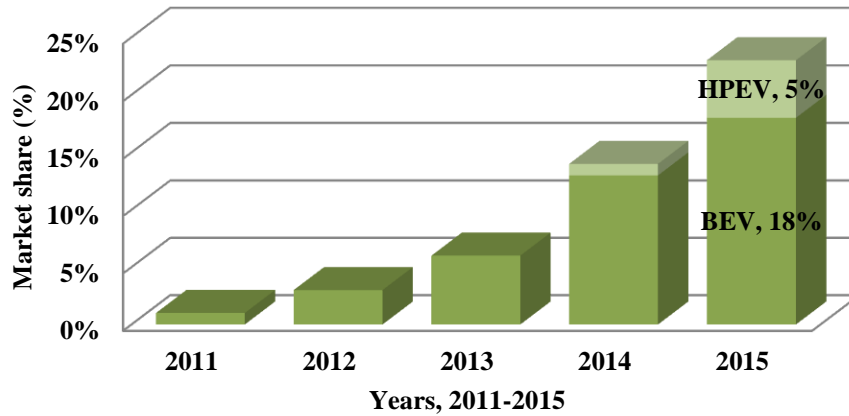


Figure 2.2: EV Market share development in Norway; Source: (IEA, 2016)

The market share of BEVs in Norway sets examples for any other countries as Norway’s BEV market share is far higher than any other country in the world. Norway has managed to reach at this point because most of its EV incentives are directed towards BEV purchases. Firstly, in Norway BEV is exempted from vehicle registration tax while the taxation on hybrids is based on vehicle weight, engine power as well as CO₂ and NO_x emission (Bjerkan et al., 2016). Vehicle registration tax is also exempted for FCEVs. Secondly, BEVs (also FCEVs) are exempted from value added tax (VAT), which is 25% of the vehicle price before tax, in Norway. Norway is the only country where BEV is exempted from VAT. Thirdly, Norway has lower rate of vehicle license fee on BEVs. Such financial incentive involves lower saving but is repetitive. Other financial incentives for BEV involves free parking on municipal public parking, exemption from road tolling and ferries fees in most counties. Finally, BEV owners in Norway have access to bus lanes. (Bjerkan et al., 2016)

In Norway Company-owned vehicles are also eligible for tax reduction; the company car tax is 50 percent lower on EVs (Holtmark & Skonhoft, 2014). Leased electric vehicles are also eligible for being exempted from 25% VAT on leasing (Norsk ebilforening, 2017).

Figenbaum and Kolbenstvedt (2013) divided the BEV development in Norway into 5 phases; (1) concept development, (2) testing, (3) Early market, (4) Market introduction and

(5) Market expansion. The five phases of BEV development are briefly described in table 2.3.

Table 2.3
The five phases of BEV development in Norway (up to 2014)

Phases	BEV development in Norway
Concept development (1970-1990)	<ul style="list-style-type: none"> • Prototypes of EVs and electric propulsion systems were developed by several Norwegian private enterprises while financial support was given from the Norwegian Research Council.
Testing (1990-1999)	<ul style="list-style-type: none"> • The first effort to commercialize Norwegian-made BEVs were launched, PIVCO and Think. • Incentives such as exemption from registration tax, toll road charges and annual vehicles license fee were set. • Introduction of free parking in municipal parking lots was made.
Early Market (1999-2009)	<ul style="list-style-type: none"> • VAT was made exempted in 2001. (Norsk ebilforening, 2017) • Access to bus lane was made permanent in 2005 after testing in larger Oslo region. • Reduced rates on main road coastal ferries was introduced as result of regional policy • Second hand import of French EVs filled market demand.
Market Introduction Phase (2009-2012)	<ul style="list-style-type: none"> • Availability of EV cars in Norway was increased during 2010/11 after the introduction of Mitsubishi, Peugeot, Citroen and Nissan launched their EVs in market. • Price competition emerged resulting rapidly falling price. • The rapid market growth probably happened from 2010 when big auto manufacturers launched larger vehicles with improved comfort and higher safety level. • Government launches Transnova and a 7 million Euro EV infrastructure program resulting in 1900 charging point at the end of 2011 (Norsk ebilforening, 2017) • First fast-charger opened in 2011

Phases	BEV development in Norway
Market expansion (2013)	<ul style="list-style-type: none"> • The number of car dealers offering electric vehicles increased. • The number of EVs passed 13,000 in the first half year of 2013 which is five-fold increase of sale from 2009. • Different business models were tested which enables single-car households to opt for EVs.

Source: Figenbaum et al, (2015)

Regarding the battery charging infrastructure, the Norwegian Government has initiated a program to finance the establishment of at least two multi standard fast charging stations every 50 kilometers on all main roads in Norway by 2017. Norwegian Parliament sets a goal that all new cars that will be sold by 2025 should have zero (electric or hydrogen) or low (plug-in hybrids) emission. It can seem very ambitious but the goal is feasible and achievable with right EV policy measures. The Parliament expects to achieve its goal by strengthening green tax system which is based on polluter pays principle. (Norsk ebilforening, 2017)

2.3 New Energy Vehicle (NEV) policy of China

Chinese government believes that moving to a future dominated by EVs rather than cars with ICE can deliver a number of major advantages; EVs can boost China's energy independence by reducing consumption of oil based fuels as China is one of the largest oil importing countries, EVs can reduce GHG emission to large extent as air pollution is considered significant problem in China and finally a large domestic market for EVs can give Chinese automakers an excellent opportunity and competence to reach the world stage (Krieger et al., 2012)

Xu Heyi, chairman of Beijing Automotive Group explained the importance of new energy vehicle development stating “(China President) Xi Jinping explained it very well, saying that developing new energy vehicles is the Chinese auto industry's only road to grow from being big to being strong” (Shirouzu and Lienert, 2015)

China has started investing in New Energy Vehicle since 2000s. Lutsey (2015) mentioned that since 2000s China has spent more than \$1 billion per year at the national level in R&D loans and grants, plus an additional \$1 billion from local governments and industry. China launched "Ten City One Thousand Vehicles" project, or the "ten city of 1000 energy-saving

and new energy vehicles demonstration application project" in 2009, and then updated the subsidiary and incentive scheme in 2013. Previously, according to subsidiary scheme of 2009, the subsidy for new energy vehicle (NEV) was provided to HEVs, PHEVs, BEVs, but in the updated policy scheme (2013) it has excluded HEVs and only subsidized PHEVs, BEVs and Fuel Cell Vehicles (FCVs). In the new scheme of 2013, in order to determine the subsidy for PHEVs and BEVs, it has adopted a simplified and more straightforward utility parameter for all electric range. In new scheme light FCVs has started receiving a fixed subsidy from 2013. (ICCT, 2013)

China provides both subsidies and vehicle tax exemptions for electric vehicles at the national level. To subsidies EV purchase, China government provides rebate that effectively reduces the purchase price for EVs. The rebate is provided at the point of sale. But to be eligible for the subsidies in China the BEVs must have a range of at 80 kilometers (km) and at least 50km for PHEVs. EVs in China are exempted from acquisition tax which is based on vehicle price, and also EV owners are benefited from lower exercise tax which is based on vehicle engine displacement and price (Yang et al., 2016). EVs are also exempted from circulation/ownership taxes in China and furthermore, in Wuhan city tolls on city road, bridges, tunnels are waived from 2014 to 2016 (IEA, 2016)

Further, similar to United States, subnational governments, e.g. Beijing, Shenzhen, Shanghai, Hefei and Hangzhou, have also provided additional incentives. The subnational governments have provided local subsidies, as well as other supplementary incentives in addition to the national incentives to accelerate electric vehicle sales. The durability of such incentive was between 2013 and 2015, (Yang et al., 2016). The local or subnational government incentives are excluded from the analysis of incentive comparison between Norway and China. In china, to encourage EV purchase, there are several policies that are implemented at various levels in different cities. For instance, the capital city Beijing discourages to purchase PHEVs strongly and has been named as the only city in China that does not provide any subsidies for purchasing PHEVs. In Beijing, the conventional vehicles are restricted from road every other day in a week but electric vehicles are exempted from that traffic restriction. Beijing, Shanghai, Shenzhen and Hangzhou, all these targeted cities have reduced the vehicle purchase and registration restrictions for EVs. In Shanghai, for example, the license plate auction price is significantly reduced only for EVs. Usually, In Shanghai, the license plate auction price for

conventional vehicles is usually as much as 70,000 RMB or equivalent of 10,000 USD (Yang et al., 2016).

As a result of large purchase incentives, various flexible traffic policies, the sales of EVs in pilot cities, e.g. Beijing, Shenzhen, Shanghai, Hefei and Hangzhou, are better than the rest of China. Beijing, Shenzhen, Shanghai, Hefei and Hangzhou - these five cities represent about half of China's 2014 and 2015 electric vehicle sales. Yang et al., (2016) made an quantitative analysis on already existing purchase incentives of different amounts (China has different purchase incentives based on different ranges and the amount of local purchase incentives varies among the five pilot cities) and sales records (EV sales per 1000 registered vehicles) of those five cities and rest of China throughout 2015 (September) taking sample of Nissan Leaf as BEV and Chevrolet Volt as Hybrid vehicle. The analysis result is shown in fig. 2.3.

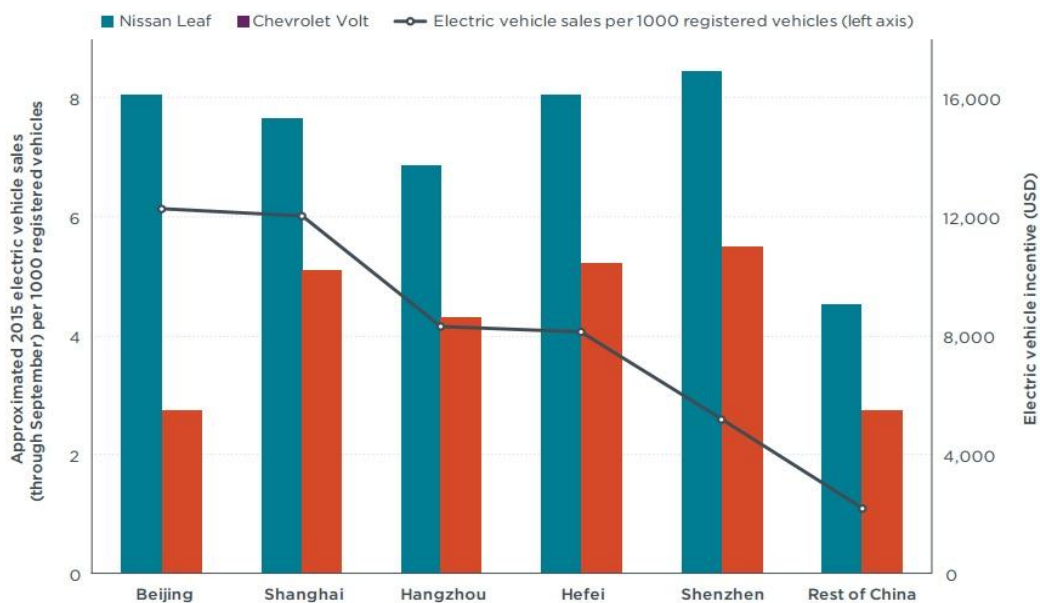


Figure 2.3: Electric vehicle incentives and approximate EV shares of new vehicles in selected Chinese cities (through September, 2015); Source: (Yang et al., 2016)

China's New Energy Vehicle (NEV) Policy framework is upgraded gradually through years. An (2016), briefly described the development of the NEV policy according to timelines which is shown in table 2.4.

Table 2.4
NEV framework development up to 2015; Source: (An, 2016)

Timeline	NEV framework development
2009-2012	China launched “10 cities, 1000 vehicles” program. The main aim of the project was the development of 10 cities each year; each city launched 1,000 new energy vehicles, through the provision of financial subsidies. The program quickly expanded to include 39 cities, and laid the foundation for the initial development of the new energy vehicle industry.
2012	The State Council of China issued “Energy saving and new energy vehicles industry development planning (2012-2020)” and set the target of 500k PHEVs and PEVs by 2015 and 5 million by 2020.
2013-2014	During the year 2013 and 2014 there was sharp increase in the number of national and local policies that encouraged the development of the NEV industry
2015	The establishment of "Made in China 2025 plan” focusing energy saving and with target to make NEVs as one of China’s 10 key sectors that should be at the forefront of development for the coming 10 years.

In 2015, the new energy passenger car stocks in Chinese market was 146,719 units (CAAM, 2016) and 2020 EV stock target is 4.6 million which includes 4.3 million passenger cars, .3 million taxis. To achieve this 2020 target China has to maintain around 6 percent EV share of all new cars that will be sold between 2016 and 2020. (IEA, 2016).

2.4 Transportation and crude oil demand

Crude oil has many applications – in producing industrial, energy and chemical products, in agriculture, for shipping, for both personal and business purposes. The demand of crude oil is largely driven by a few sectors, especially transport sector. From year 1932 to 2012, the consumption of crude oil in transport sector has increases from 1022 million ton to 2036 million ton of oil equivalent (mtoe) on an annual basis (Global Petrol Price, 2015). In 2012, the global transport sector accounts for 64% of global crude oil consumption (fig. 2.4)

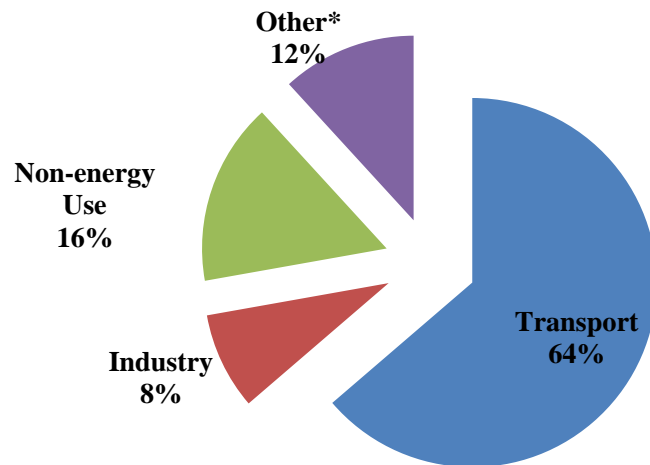


Figure 2.4: Global crude oil consumption in 2012 by sector; *Source: (Global Petrol Price, 2015) *includes agriculture, building, commercials, public services and others*

According to BP statistical review (2016), China accounted for 23% of global energy consumption and 34% of net energy consumption growth. In China, among the fossil fuels, consumption growth was led by oil (+6.3%) in 2015, followed by natural gas (+4.7%). According to IEA statistics transport sectors in China accounted for over 40% oil demand in 2010 while motor gasoline, gas/diesel oil being the main transportation fuels. In 2015 China’s oil consumption was 11.97 million barrels per day which accounted 12.9% of global oil consumption (BP statistical review, 2016).

BP Energy Outlook (2016) estimates the growth in the global consumption of liquid fuels is mostly driven by two sectors: transports and industries; with transports accounts for almost two-third of the growth (fig. 2.5). The growth in demand by transport sector ascertains the rapid growth in vehicle ownership, especially in emerging economies e.g. China, India. The global vehicle fleet, both commercial and passenger cars, will be more than double by 2035 while Non-OECD vehicle fleet will grow more than triples, overtaking the OECD in the early 2020s (fig. 2.6). Moreover, BP Energy Outlook (2016) estimates that the transport fuel continues to be dominated by oil; which accounts for 88% in 2035. (BP Energy Outlook, 2016)

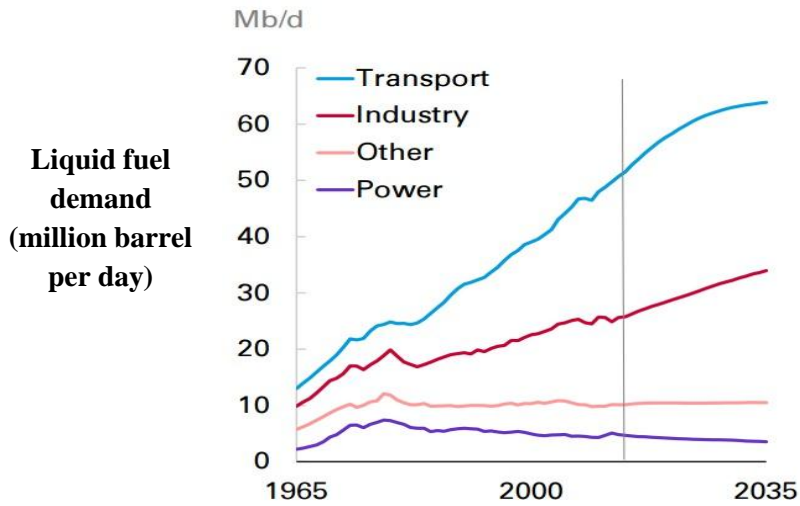


Figure 2.5: Liquids fuels demand by sector: *Source: (BP, 2016)*

Note: In this graph, transport includes aviation, navigation, road and railroad traffic, and pipeline transport, as per IEA definitions.

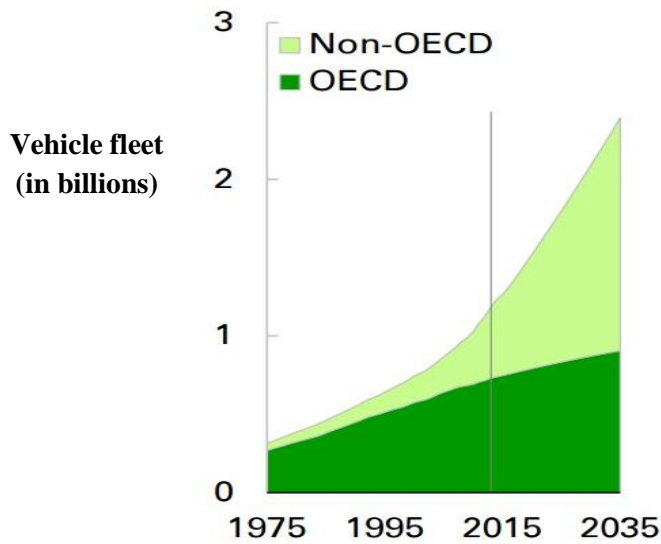


Figure 2.6: Vehicle fleet growth in OECD and Non-OECD countries, *Source: (BP, 2016)*

2.5 Comparison between Norwegian EV policy and New Energy Vehicle (NEV) Policy of China

From the descriptions given in above sections, differences between Norwegian EV policy and Chinese New Energy Policy are evident. Table 2.5 summarizes the differences. IEA (2016) categorizes the EV policy measures into purchase incentives, Use incentives and Waivers on access restrictions. In this chapter of the research, the EV policy of Norway and New Energy Vehicle (NEV) policy of China is described under those three categories.

- EV Purchase Incentives includes rebates at registration/sale, sales tax exemption, VAT exemptions, and tax credits.
- EV Use Incentives includes Waivers on fess (e.g. road tolls, parking, and ferries), lower tax for company cars, electricity supply exemption.
- Waivers on access restriction include Access to Bus lanes, Access to restricted traffic zones and Access to HOV lanes.

In this research, only the policy measures that are relevant for China, Norway and the policy measures that deem to influence EV sales largely are described comprehensively for analysis purpose; e.g. tax credits and access to HOV lanes, neither Norway nor China has these policy measures (Sweden and united States has tax credit policy for electric vehicles, Canada and United States have the policy of access to HOV lanes but limited to only targeted areas).

Table 2.5
Differences between Norwegian EV policy and Chinese New Energy Policy

Policy measures	Norway	China	
Rebate at registration/sale	-	Nationwide policy	EV Purchase Incentives
Sales tax exemptions (Excluding VAT)	Nationwide policy	Nationwide policy	
VAT exemption	Nationwide policy	-	
Lower tax for Company car	Nationwide policy	-	
Waiver on fee (Tolls, parking and ferries)	Nationwide policy	Targeted policy	EV use Incentives
Electricity supply reduction/exemption	Targeted Policy	Targeted policy	
Access to bus lane	Nationwide policy	-	Waiver on access restrictions
Access to restricted traffic zones	-	Targeted Policy	

Source: IEA (2016)

In table 2.5 Targeted Policy refers that Policy is implemented in certain geographical areas (e.g. Specific states/regions/municipalities), affecting less than 50% of the country's inhabitants.

2.5.1 EV purchase incentives

I) Rebate at registration/sale:

China, United Kingdom, Germany offer both subsidiary (includes income tax credits and vehicle purchase rebates) and vehicle tax reduction (includes both one time and annual vehicle tax reduction). Norway doesn't have policy for rebate at registration or sale. In China, the new energy vehicle subsidiary policy includes a one-time bonus or rebate for new energy passenger cars, though the exact monetary value of this purchase incentives generally varies across buyers and all new energy passenger car models. The rebate is between 35,000 RMB and 60,000 RMB (about 4,200 EUR –7,200 EUR) for BEVs, depending on the battery range of the BEVs, and 35,000 RMB (about 4,200 EUR) for PHEVs with battery range no less than 50 km. This rebate policy for BEVs and PHEVs was extended through 2015. Afterwards China has proposed to provide rebates of ranging 32,000 RMB-55,000 RMB per new energy passenger car for period of 2016-2020 (Lutsey, 2015). According to government's policy planning, the monetary value of purchase incentive decreases by 20% in period 2017-2018 and further 20% in period 2019-2020. (An, 2016)

II) Sales tax exemptions (excluding VAT):

Both Norway and China have sales tax exemption policy for EVs. In China, all types of EVs (excluding HEVs after amendment of 2013) are exempted in tax scheme but in Norway only BEVs are given priorities above all.

Table 2.6
Tax scheme differences between Norway and China

Region	Tax Scheme		Timeline
	One-Time	Annual	
Norway	Registration tax: BEVs are exempted but PHEVs are charges based on vehicle weight, engine power, Nitrogen oxide and CO ₂ emission	-	Government reinstated incentives through 2017
China	EVs are exempted from Acquisition tax and exercise tax	EVs are exempted from vehicle and vessel fee	Tax rate is fixed

Source: (Yang et al., 2016)

In China, economic factors such as purchase incentives are considered as the key reason to motivate the buyers to purchase EVs. In China, 66.8% of the customers expressed that vehicle price is crucial for deciding whether to buy or not, and then they ranked saving money on fuel costs (Tan et al., 2014). In China, the price of EVs is higher than ICE vehicles

even after deducting the national level financial subsidies. In fig. 2.7, the price of few top sold (in 2016) EVs after deducting the national subsidies and top sold ICE vehicles are compared. In China, the top two models were PHEVs among the EV models sold in 2016. Marro et al., (2015) urge that one of the obstacles of EV adoption in China is the high price tag.

On the other hand, In Norway the purchase incentives in combination of other user incentives have been proved effective to accelerate the adoption of EVs. The incentives provided in Norway gives relative advantages that are not available in other countries. Serafimova (2015) states that as a result of the financial incentives, the ownership cost of EVs has been lower than that of ICEs counterparts in Norway.

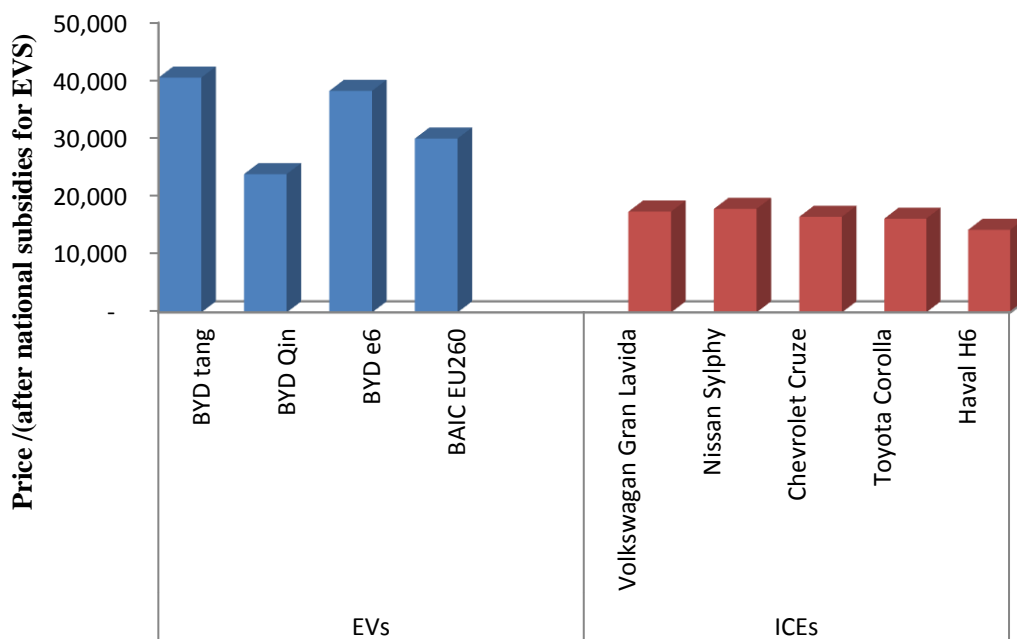


Figure 2.7: difference between price of ICEs and EVs after national subsidies deductions, in China; Source: evolita.com, chinaautoweb.com and An (2016)

Note: February currency exchange rate was considered while converting the price from RMB to USD

III) Value Added Tax (VAT) exemption

In addition to the exemption of registration tax, in Norway VAT (25%) is exempted for BEVs. But VAT exemption is not applies for PHEVs. Mock and Yang (2014) mentioned that the saving for VAT exemption in Norway is about 4,500 EUR (for the Renault Zoe). VAT is usually applied to the base price of the electric vehicles, excluding any purchase/registration tax. In all electric automobile markets other than Norway, EV owners are usually paying

more VAT than conventional vehicles (ICE Vehicles). This happens as EVs usually have higher base price and hence ended up with higher VAT, despite of the bonus or rebate deduction from the base price, e.g. in China and Japan (Mock and Yang, 2014). In China, the VAT is 17% but it is not exempted for EVs.

2.5.2. EV use incentives

I) Lower tax for company cars

In China automobile producers can sell EVs to rental enterprises at the price excluding the subsidies (Tan et al. 2014) while in Norway BEVs has 25% VAT exemption on leasing (Haugneland et al., 2016)

II) Wavier on fees(tolls, parking)

In Norway BEV is exempted from paying toll fees, parking fees and ferry fees. The Policy is implemented national-wide. Fearnley et al., (2015) calculated the annual average economic value of such incentives for the average Norwegian EV driver. Fearnley et al., (2015) calculated the annual average economic value displays in table 2.7 based on few assumptions:

- The value of the toll-road exemption calculation is associated with uncertainties and the value is assessed by combining two information : respondents' stated usage of toll-road, and the cost of the toll-road that the respondents' could be using, given maximum available rebates
- The value of free parking is measured based on weighted average of respondents' stated weekly saving.
- The reduced ferry price is estimated based on respondents' ferry rate savings. Here, consideration was taken that different municipalities have different rate for ferry.

Table 2.7

Calculated average values per year of different local incentives per car and for total fleet in Norway Total fleet in Norway = 25 000 EV's in April 2014. (Euros/year).

Incentives	Value per car Euro/year	Value for EV fleet million Euro/year
Toll road	434	11
Free Larking	398	10
Free Ferries	145	4

Source: Fearnley et al., (2015)

For China, this policy measure is implemented in certain geographical areas, e.g. Wuhan city tolls on city road, bridges, and tunnels are waived from 2014 to 2016 (IEA, 2016)

2.5.3 Waivers on access restrictions

I) Access to bus lane and restricted traffic zone

Myklebust (2013) expressed that bus lane incentive as controversial incentive considering several aspects. Access to bus lane is considered as one of the strongest incentives that allows EV drivers to use the bus lane and this incentive has already proved that it contributed to increase the EV market share (table 5.4). Myklebust (2013) argued that the main target behind letting EVs into bus lane was not to let well-off commuters or car buyers save time to work. Instead the main target was to accelerate the introduction of electric vehicles in Norwegian transportation system. This incentive applies all over Norway but certainly saves more time in more traffic-dense cities such as in Oslo. The controversial part is that EV numbers are growing every year gradually in Norway and it leads to growing concern that sooner or later EVs will obstruct bus traffic to an extent that may make it impossible to continue such access.

II) Access to restricted traffic zone

In china they don't have the policy to allow access the EV cars to bus lanes but they have policy to allow EVs to restricted traffic zones.

2.5.4. Supporting policy measures

I) Electric Vehicle Supply Equipment (EVSE) or Charging Infrastructures

As per IEA (2016) China accounts for 44% of the total number of fast charging outlets in 2015, down from 53% in 2014. But the scenario is different if charging infrastructures (EVSE stock) per million inhabitants is accounted for. In 2015, Norway's total charging infrastructures per million inhabitants was 15,143 and publicly accessible charging infrastructures per million inhabitants was 1,372 while for China the numbers were 265 and 42 respectively. IEA (2016) suggests that countries with high charging infrastructures rate per capita have typically developed attractive charging infrastructures implementation incentives. Local government and Manufacturers in Norway offer free recharging service to develop EV owners' confidence in this new technology and its usage practically. Moreover, in order to accelerate the charging points nationwide, Norway provides subsidy that value to up to Euro 6000 a year per EV for the installation of charging points in residences or home. Because of organized and planned initiatives for installation of charging points, it is now possible to

drive an EV from south of Norway to the Russian Border – a distance which is equivalent to driving from Oslo to Rome; thus evidence has been set that the limited driving range of EVs is only a psychological barrier now (Serafimova, 2015).

Tan et al., (2014) finds out that in China there are two problems regarding the charging infrastructure: one is the insufficiency of charging infrastructure, and the other is long charging time. Concentrated charging points in people intense place e.g. supermarket vehicle parking lots and town center vehicle parking lots certainly influence the conscientiousness and likelihood to buy electric vehicle. Tan et al., (2014) also mentions that building mass charging infrastructure process in China is going on but for short term period the lacking of charging infrastructure is unavoidable. The year-over-year growths of installing charging infrastructures both in Norway and China are shown in below fig. 2.8. It displays that in China the growth of building charging infrastructures falls largely in 2013 from the point of 2011. Even there is an increase only for one year (2014) but then the year-over-year growth rate falls again in 2015. On the other side, in Norway, the year-over-year growth starts to increase gradually from 2013 and up-to 2015 it keeps increasing.

Olczak (2015) urged that currently China's sales of electric vehicles are picking up speed after putting long effort but faster installation of charging Infrastructures along with effective financial or purchase incentives are necessary for conclusive shift of consumer demand. Marro et al. (2015) pointed out that even though central government of China has already taken worthy steps in pushing for development of charging infrastructure, still there are no national infrastructure standards; so concern is that a vehicle built in Shenzhen may face operability issues in Shanghai or vice-versa as a result of the differences in communication protocol between the model and local grid (Marro et al., 2015)

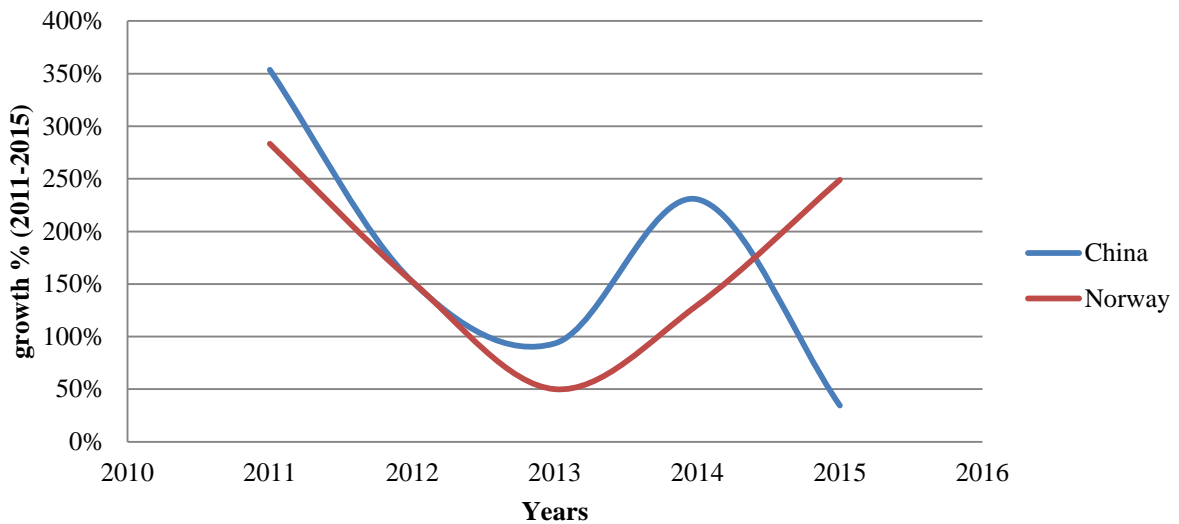


Figure 2.8: Growth of installing fast charging stations over years, 2011-15; Source: IEA (2016)

II) Communication process:

Zhang et al., 2011 analyzed that most of the consumers in China only have limited acquaintance with EVs. Most of the consumers or buyers who are familiar with EVs, only know that EVs are environmental friendly but they don't know much about EVs' performance, the maintenance cost, or the charging intervals of EVs. As a result, government's EV policy measures make negligible differences to develop consumers' EV purchasing willingness. In a study on the EV choice preference of China consumers, survey reveals that 32% of respondents don't have understanding about the concept of new energy vehicles (iCET, 2016). Zhang et al., (2011) suggested that in order to promote the development of EV adoption, it is necessary to enhance consumers' awareness and knowledge about EVs as whole e.g. EVs' benefits, performance, maintenance, cost, both national and local level purchase incentives and other policy measures. Zheng et al, (2012) urges raising public awareness about EVs as one of the challenges for China. Up to the date of study, 2012, only few cities started to raise public awareness about the green energy vehicles through mass media such as TV, radio broadcast, newspaper but most of the other cities were still relying on the auto manufacturers to promote their green energy vehicles (Zheng et al., 2012)

On the other side, In Norway, combined with the incentives making BEVs more affordable than conventional vehicles, the increased knowledge of BEVs has makes more people considering buying a BEV (Figenbaum et al., 2015).

Larson et al., 2014 revealed that consumers' knowledge about EVs plays role in making EV purchase decisions, and the information should be from objective and trustworthy sources, including word of mouth. Larson et al., (2014) also recommends that government needs to play the vital and main role in investing research, distributing objective information, and educating consumers about the necessary information of EV that can develop willingness to purchase EV. Figenbaum and Kolbenstvedt (2015) assert that communication process has supported EV diffusion in Norway. The communication process includes organizations helping users, the car industry and the initiation of establishing different channels for cooperation between organizations, public authorities and car industry. Moreover, a large media exposure has grown parallel to the development of the market. Different diffusion agents have also contributed to raise awareness and to initiate some tests. (Figenbaum & Kolbenstvedt, 2015)

III) Availability of EV brands and models:

Figenbaum et al. (2015) suggests that the sale of BEVs depend not only on incentives but also on the availability of BEVs in the market. As mentioned in table 2.3 the BEVs market in Norway expanded rapidly after the introduction of new models in the market. The recent EV sales in China also reflect the impact of readily availability of EV models. In China the models availability increased very rapidly compared to other countries in the period of 2012-2015 and also China managed to increased sale of EVs largely in recent years. Fig. 2.9 and fig. 2.10 together illustrate that readily availability of EV models has somewhat correlation with the increase of EV sales. But for some countries the correlation is not positive or strong enough e.g., fig. 2.10 shows that even Japan has increased its EV model it didn't manage to have positive growths in year 2014-2015. Fig. 2.9 includes the data from 2012-2015 and shows the availability of EV models across different countries. The numbers of models represented in the fig. 2.9 are estimated, and do not include models with low sales. Fig. 2.10 illustrates the sales increase or growth percentage compared to previous years in countries. Fig. 2.10 shows that For two consecutive years, EV sales in Denmark and China have doubled or tripled the previous year's totals (Yang, 2016).

Olczak (2015) showed concern that though in recent years China has increased the model numbers of electric vehicles, buyers are not getting models according to their choice and the problem has been already acknowledged by local government. In China the foreign EV models have high import tariffs and moreover, foreign EV models are excluded from

government catalogues of EVs qualifying for subsidies. As a result the Chinese EV buyers' buying option is limited to domestic models that have been relatively unpopular among brand-conscious buyers (Olczak, 2015). iCET (2016) analyzed China consumers' willingness to pay for a brand based on its country of origin and result shows that people prefer German brand most while Korean, Japanese, American and Chinese stands second, third, fourth and fifth respectively. This results shows that China consumers are willing to pay more for brand from other countries over Chinese brands and Chinese EV market is dominated by Chinese brands and models which reflects that the availability of different brand and models can increase the EV market share in China. Marro et al., (2015) mentioned that in China automobile ownership is labeled as status and success but car buyers still prefer conventional cars because they have more classis and internationally-recognized models of conventional cars in market compared to EVs.

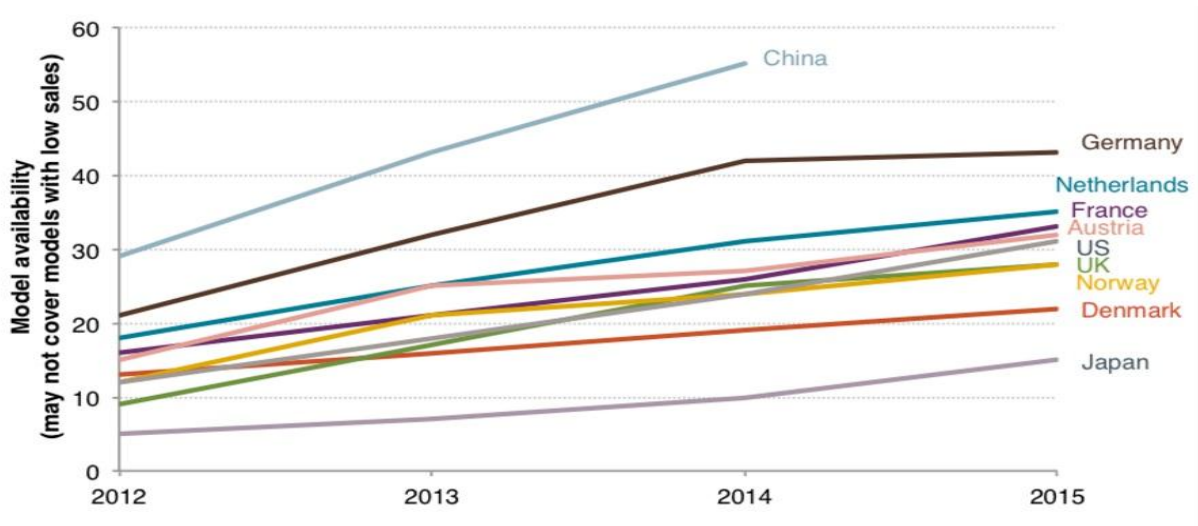


Figure 2.9: EV Model availability in different countries, 2012-2015, Source: (Yang, 2016)

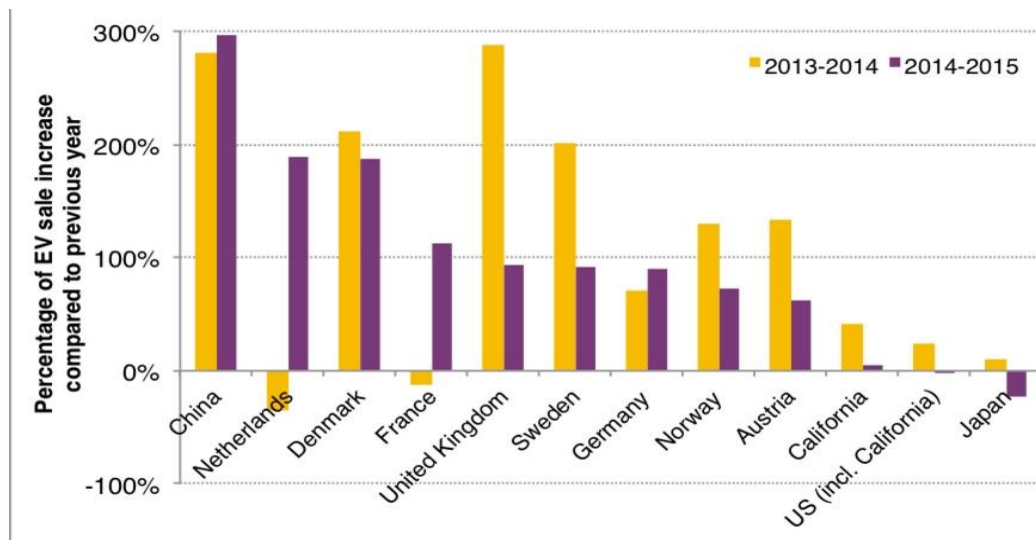


Figure 2.10: Percentage of EV sale increase compared to previous years; Source: (Yang, 2016)

2.5.5 Summary of comparison of the policy measures

From the description of the last few sections it is clear that there are more than one difference between Norwegian EV policy and China NEV policy. Table 2.8 summarizes the China’s standing on individual policy measures grounded on the differences compared to Norwegian EV policy and suggests if China can consider adopting the policy measures. Fearnley et al., (2015) summarized the evaluation of Norwegian EV incentives to uptake the EV market in Norway. Fearnley et al., (2015) summarizes the information based on Figenbaum et al. (2014)’s research analysis.

**Table 2.8
Summary of comparison of EV policy measures**

Policy measures	Importance for uptake (for Norway), Fearnley et al., (2015)	China’s standing (based on the comparison)
Exemption from registration tax/ rebate* (for China)	Only important in market niches	Already existing; still EV prices are higher than conventional vehicles in many cities except the pilot cities where additional local incentives are provided.
VAT exemption	Crucial factor	May consider to adopt since still EV prices are higher than conventional vehicles in many cities

Policy measures	Importance for uptake (for Norway), Fearnley et al., (2015)	China's standing (based on the comparison discussed in Chapter 2)
Reduced annual vehicle license fee	Only important in market niches	Already existing
Free toll roads	Crucial factor	may consider to adopt nationwide
Access to bus lanes	Crucial factor	may consider to adopt nationwide
Free Parking	Only important in market niches	Targeted policy, may consider to apply national-wide
Access to restricted traffic zone*	N/A	Targeted policy, may consider to apply nationwide if applicable for other cities as well.
Charging Infrastructure	N/A	In Norway publicly accessible charging infrastructures stock per million inhabitants was 1,372 while for China the number is only 42.
Availability of models or brands	N/A	China has more models than Norway but China consumers are willing to pay more for brand from other countries over Chinese brands and China EV market is dominated by China brand EVs
Communication	N/A	Previous studies suggest raising awareness as one of the challenges for China.

Note:

**1) Norway doesn't have any restricted traffic zones*

2) Norway doesn't have rebate system; but already with current tax exemption EV prices are competitive with conventional vehicles

N/A = evaluation of those incentives where not mentioned in Fearnley et al., (2015)

Chapter 3: Theoretical Framework

Recently, we are witnessing a new wave of interest in electrification of vehicles around the world. Electrification of vehicles is not only important for reducing the environmental impact or greenhouse gas (GHG) emission but also for national energy security for many countries, (e.g for China) and economic development. Speculators have several speculations about how rapid the market share of electric vehicles will grow in coming years but the last few years' market growth asserts that the electric vehicle market is growing very fast. Renault- Nissan CEO Carlos Ghosn said, "The electric car appeared at the beginning of the century, then disappeared, appeared in the 1950s, then disappeared, appeared in the 1970s, then disappeared. But a lot of things have changed.... We are putting our chips and we are putting our investment and we are putting our efforts behind this belief that now is the time." (Yale Environment 360, 2011)

There's lots of enthusiasm and encouragement in electric car markets that even competitors are also encouraging each other to boost the market. As CEO and Product architect Elon Musk said "I really do encourage other manufacturers to bring electric cars to market. It's a good thing, and they need to bring it to market and keep iterating and improving and make better and better electric cars, and that's what going to result in humanity achieving a sustainable transport future. I wish it was growing faster than it is" (Badkar, 2013). The founder of Virgin group Richard Branson also showed interest in this electric vehicle industry, "We have teams of people working on electric cars. So you never know - you may find Virgin competing with the Tesla in the car business as we do in the space business" (Reuters, 2015)

Greene et al., (2013) suggests there are barriers that need to be overcome for the transition to electric drive vehicles and the barriers are a) technological limitations which includes the limited range of electric vehicle cars and long charging time, b) lack of EV model diversity or lack of diversity of choice, c) risk aversion which exposes the need to accomplish learning by doing, d) the higher purchase cost of EVs and most importantly, e) the lack of energy supply infrastructures or simply charging infrastructures. (Greene et al., 2013)

The invention of electric vehicles is nothing new; electric vehicles first appeared almost a century ago but the currently available electric vehicle models in the automotive markets are based on innovative, advanced technologies and therefore, electric vehicle is treated as innovative products in studies. Petschnig et al. (2014) suggests that electric vehicle adoption

can be considered as an innovation adoption behavior. As electric vehicle is a technological innovation, the adaptation of electric vehicles can be explained by innovation diffusion theory (Rogers, 1983). The influence of different electric vehicle policy measures, such as purchase incentives, use incentives and waiver facilities for EVs, can be explained by transport demand theory (Button, 2014 and Mathisen, 2008). Furthermore, to understand the long-term economy of the transition of electric vehicles, the explanation from Greene and Lui (2014) (described in section 3.3) is necessary. Section 3.4 accounts for modeling for EV adoption which can be used to measure EV market share changes in the influence of different EV policy measures. The necessary quantitative analysis models are represented in section 3.5 of this chapter.

3.1 Diffusion of Innovations

Rogers (1983) defines diffusion as a process by which an innovation is communicated over period of time among the members of a social system. Such communication is done through certain channels and this special type of communication differs from usual communication in a sense that in such communication messages are concerned with new ideas.

3.1.1 Innovativeness and Adopter Categories

The Criterion for adopter categorization is innovativeness and according to Rogers (1983) definition, innovativeness represents the degree to which an individual or any other unit of adoption process is relatively earlier in adopting new ideas than other members of a social system. Innovativeness is a relative dimension¹ and a continuous variable, and partition it into discrete categories is only a conceptualization which resembles categorizing the continuum of social status into upper, middle and lower classes. Rogers (1983) mentioned that the adopter categorization is a simplification that eases the understanding.

Normal frequency distribution has several characteristics or parameter; two of them are: a) mean (\bar{x}) or average, and b) standard deviation (sd), which is a measure of dispersion of a distribution about the mean. In innovation adoption categorization process, mean (\bar{x}), and standard deviations (sd) are used to divide a normal adopter distribution into categories. In graph, the vertical lines are drawn to mark off the standard deviations on either side of the mean and the curve is divided into categories in a way that results in a standardized percentage of respondents in each category. Fig 3.1 shows the normal frequency distribution divided into five specific adopter categories: (1) innovators, (2) early adopters, (3) early

¹ Innovativeness is a relative dimension as one has either more or less of it than others in a social system (Rogers, 1983)

majority, (4) later majority, and (5) laggards. Along with the five adopter categories, the estimated percentages of individual adopter categories are positioned on the adopter distribution curve in fig. 3.1. The area lying to the left of the mean time of adoption minus two standard deviations is the first 2.5 percent of the individuals or other decision making units who are labeled as innovators; the next 13.5 percent are labeled as early adopters and the next 34 percent are labeled as early majority. Early majorities are usually slower in adoption process than the innovators and early adopters. Between the mean and one standard deviation to the right of the mean time of adoption is located the next 34 percent to adopt the new idea who are labeled as the late majority and they are usually skeptical about adopting innovations. The last 16 percent are called laggards and they are usually mostly focused on traditions. From the fig. 3.1 it is understandable that the adopter classification is not symmetrical as there are three adopter categories to the left of the mean and only two to the right. The critics question if the laggards can be divided into two categories rather than being a single category but laggards seem to form homogenous categories and therefore dividing the laggards into two categories might not be the perfect solution. On the other hand, it is also suggested that if innovators and early adopters can be a single category to achieve symmetry but innovators and early adopters have quite different characteristics that it is perfect to define them as two distinct categories.

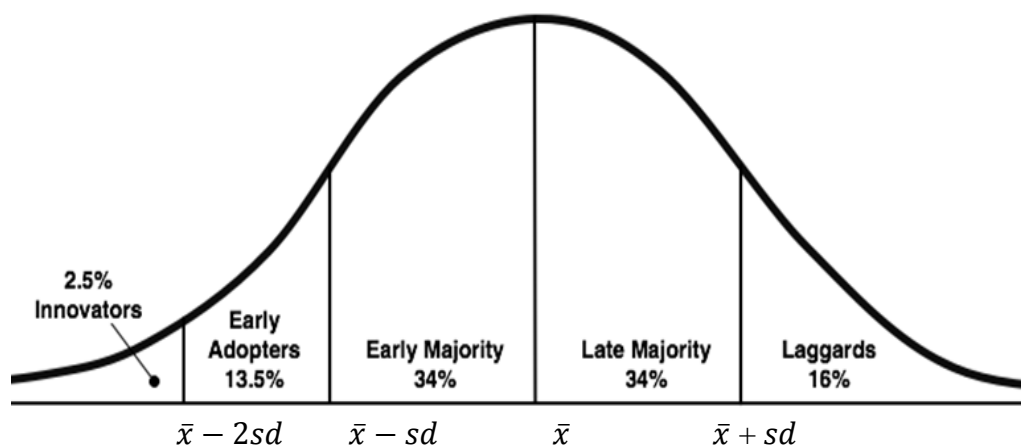


Figure 3.1: innovation adopter categories; source: (Rogers, 1983)

3.1.2 The Innovation-decision process

Rogers (1983) defines the innovation-decision process as a process through which an individual or any decision making unit passes from the first knowledge of the innovation to form decision to adopt or reject, to implement of the new idea and to confirmation of this decision. The innovation decision process includes five stages; 1) Knowledge 2) Persuasion

3) Decision 4) Implementation and 5) Confirmation. Fig. 3.2 briefly demonstrates the five stages of the innovation-decision process.

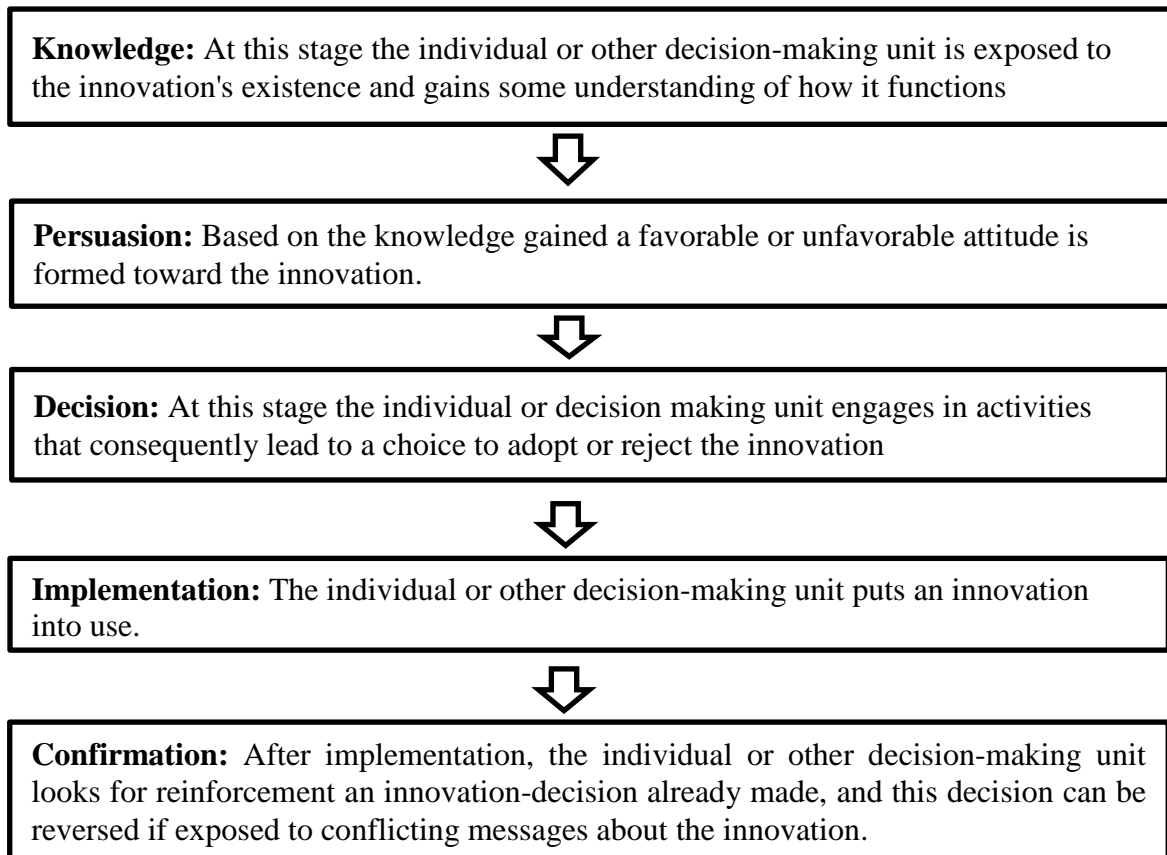


Figure 3.2: Innovation-decision process with 5 stages; source: (Rogers, 1983)

It is certain that the innovation-decision process relies on information flows and the information flows through different communication channels. Rogers (1983) defines communication channels as the means by which message flows from sources to a receivers. Communication channels can be categorizes as either interpersonal or mass media in nature. Mass medium channels include the means of transmitting messages that involves mass media, e.g. radio, television, newspapers. In other words, mass media is a channel that enables an information or message from a source of one or few individuals to reach many audiences or mass people. Mass media can reach a large audience rapidly and also can create knowledge besides spreading information. On the other side, interpersonal channels involve a face-to-face exchange between two or more individuals in a social system. Interpersonal channels have greater effectiveness in dealing with resistance or apathy on the part of communication. The important feature of Interpersonal communication is that it provides a two-way exchange of information. (Rogers, 1983)

Communication channels can be categorized further based on originating as either cosmopolite² or localite (local) channels. Interpersonal channels can be either local or cosmopolite but mass media channels are almost entirely cosmopolite.

Rogers (1983) concludes the importance of different communication channels at different stages.

- Mass media channels are relatively more important than interpersonal channels at the knowledge stage. Furthermore, mass media channels are more important for earlier adopters than for later adopters as well. On the other side, interpersonal channels are relatively more important than mass media at the persuasion stage in the innovation-decision process.
- Based on importance of the origin of the information or knowledge, cosmopolite channels are relatively more important than local channels for earlier adopters than for later adopters.
- The innovation-decision period is the length of time required to pass through the innovation-decision process and in such process earlier adopters have a shorter innovation decision period than later adopters.

². Cosmopolite communication channels are usually those from outside the social system being investigated (Rogers, 1983)

3.2 Factors to influence transport demand

Button (2014) defines demand as an abstract concept which reflects what individuals (consumer) would like to consume under various scenarios. Usually quantity demanded of a commodity, denoted as D_a , is influenced by its price, P_a , the price of other goods, P ($p_1, | P_2 \dots P_n$), tastes, T , and the level of income of consumers, Y . Therefore,

$$D_a = f(P_a, P_1, P_2 \dots P_n, T, Y) \quad (1)$$

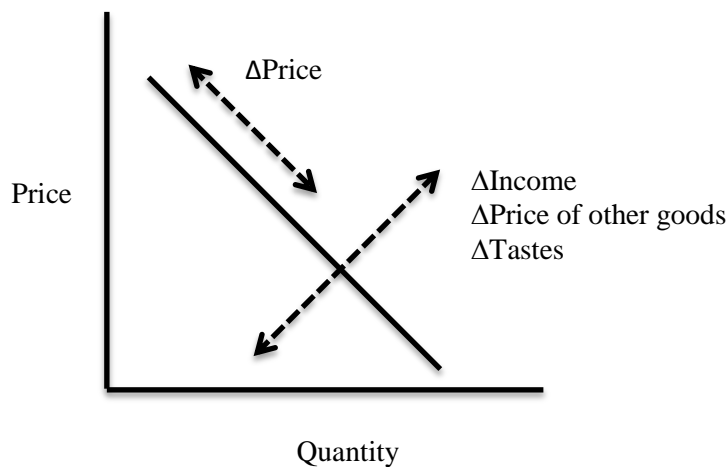


Figure 3.3: simple demand curve; *Source: (Button, 2014)*

The effects of price change on passenger car transport are divided between the effect on vehicle ownership cost and on vehicle use cost (Button, 2014).

Usually there is negative relationship between price and quantity demanded, provided all elements in the Eq.1 remain constant. This negative or reverse relation between price and demand creates the downward sloping demand curve which means that if price increases the demand falls and if price falls the demand usually increases holding all other elements constant. The demand curve shifts if elements, such as income, tastes and price of other goods changes, for example, a fall in the price of substitute makes the goods relatively more expensive and pulls down the demand at any price or the increased income of buyers increases the affordability and results in the shift of demand curve upward. The adoption of EVs is largely related with the price of EVs. Thus, if the price of EVs get competitive by initiating purchase incentives, it can increase the EV demand in market while, in contrast, if

EV competitor, ICE vehicles' price gets high by imposing more taxes, VAT and fees then it will also make the demand of EVs to increase and demand of ICE vehicles to decrease.

Moreover, the elements in Eq. 1 may represent complex compound of several interacting factors. For example, price may include all type of costs involved in obtaining the transport service of which 'time cost' is generally held as one of the most important factor in transport economics. (Button, 2014)

Mathisen (2008), in generalized cost notion, suggests that a rational car buyers do not only consider transport as opposed to the cost of other goods, but buyers also choose transport mode based on the factors that gives them lowest generalized costs for the specific travelling distance.

$$G(Q, R, D) = P(D) + T(Q, R, D) \text{ where, } G_Q < 0 \text{ and } G_R, G_D, G_P > 0 \quad (2)$$

Here, the generalized costs, denoted as G, are expressed by fare, P, and time cost, T. The fare, P increases with distance, D, while time cost, T, increases with distance, D, and income, R, but reduces with quality, Q.

Mathisen (2008) described that the generalized cost notion expresses the cost of making a trip and how cost of trip influences demand for transport according to the generalized cost elasticity.

$$E = E(G); \text{ where } E_R, E_D, E_P < 0, E_Q < 0 \quad (3)$$

The demand for transport, E, in Eq. 3 is constantly expressed as a function decreasing with respect to generalized cost (Mathisen, 2008). The EV policy measures, allowing EVs to have access in bus lane saves the time of EV buyers and thus it involves the cost of time from generalized cost notion.

3.3 The economy of large-scale energy vehicle transition

Greene and Lui (2014) suggest that an appropriate metric for evaluating the transition policies of transition to electric vehicles from conventional vehicles is the present value of future economic welfare. Greene et al., (2014) conducts net present value analysis of the transition to electric vehicle considering, for simplicity, two types of benefits: private (B_p) and Public (B_u) and two types of costs: subsidies to fuel (C_f) and vehicles (C_v). Other assumption includes the benefit and cost functions may vary over the time interval of interest

($t=0, T$) and both benefit and cost are function of an $n \times t$ matrix of state and policy variable (X_t) whose time dimension increases over time as $t \rightarrow T$.

The NPV³ equation established by Greene et al., (2014) to evaluate the transition of electric vehicles

$$NPV = \sum_{t=0}^T \frac{1}{(1+r)^t} [B_{pt}(X_t, b_t) + B_{Ut}(X_t, b_t) - C_{FT}(X_t, b_t) - C_{vt}(X_t, b_t)]$$

Where X_t is a matrix and b_t is a vector (the costs (C_f and C_v) and benefits (B_p and B_u) are function of a vector of parameters, b_t , and its value may change over time)

Greene and Lui (2014) suggest that a change in single variable of transition policies in any year may impact all other variables in that year and in all subsequent years up to T . For example, increasing the subsidy for electric vehicles will increase the subsidies paid out in that year, even assuming the electric vehicle sales constant. As a result of increasing subsidy, electric vehicle sales will increase which will not further increase the subsidies for electric vehicles but will have cascading effect on other variables in succeeding years. Increase in electric vehicle sales will increase scale economies and learning. The economy of scale will further reduce the cost of electric vehicles and learning will further increase sales in future years. Increased electric vehicle sale might increase the electricity supply subsidy costs if the electricity supply for electric vehicle is subsidized. Increasing electric vehicle sales reduces the risk aversion of majority electric vehicle buyers. However, as electric vehicle sale starts increasing, the willingness of other innovators (except the most eager innovators) and early adopters to pay for electric vehicle (novel vehicle technologies) starts decreasing (figure 3.4).

As an explanation of the decrease willingness to pay, assume the optimal number of electric vehicles that should be sold (purchased) in year t . The positive net present value (NPV) for optimal transition implies that the increasing number of electric vehicles in year t from nothing (zero) to some positive value will have positive marginal impact on the net present value (NPV) and this marginal improvement in net present value (NPV) of benefits from selling one additional electric vehicle in year t refers as the willingness of society to pay for sales of electric vehicles. To measure if the NPV of benefits is increasing or decreasing, a

³ Greene and Lui (2014) suggests that “net present value (NPV) of an energy transition, in this case transition of electric vehicle, can be calculated by the discounted value of stream of changes in both costs and benefits relative to reference or base case projection”

second derivative⁴ of NPV benefits with respect to vehicle sale is required to be conducted and if second derivative shows negative results then it implies the societal willingness to pay for electric vehicles will decrease with increasing sales, sketching down a downward-sloping curve (demand), as demonstrated in figure 3.4. (Greene and Lui, 2014)

Nevertheless, at the same time the market or buyers in the society has willingness to purchase, additional electric vehicles. Greene and Lui (2014) suggest that at the beginning of penetration of electric vehicles in the market, it may be easy to sell because of the most eager innovators but gradually its gets somewhat more difficult to sell and so on. At this point the necessity of application of subsidies appears. The subsidies and investments (for policy measures and R&D) for selling the electric vehicle is the cost of society. Thus, the increase of subsidies (incentives) and investments are deemed necessary up to a certain level to ensure the sale of each additional electric vehicle traces out the willingness-to-accept (or supply) function of market for electric vehicles.

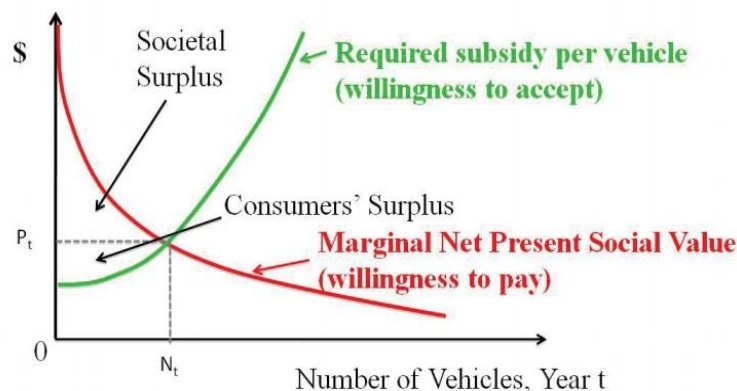


Figure 3.4: Determination of an efficient quantity of electric vehicle sales in year t and an efficient subsidy. Source: (Greene and Lui, 2014)

Note: This explanation ignores the existence of tipping point⁵ which is, in fact, an important feature of the novel transport transition problem. One significant consequence of tipping point in system is that the demand curve for electric vehicles will not, in general, be smoothly downward sloping.

⁴ The first derivative shows if a function is increasing or decreasing and second derivatives shows if the first derivative is increasing or decreasing.

⁵ Tipping point happens when gradual impact of one or more control variables brings discontinuous changes in system. (Greene and Lui, 2014)

3.4 Modeling for EV Market Share (EVMS model)

Logistic model and Gompertz model (Tang et al., 2013; Ding et al., 2013) are commonly used to forecast the car ownership rate where economic growth (GDP per capita) and population are considered as main factors. Unger (2015) used statistical model to predict the total vehicle-in-use. The common aspects of these models are that all of them did the forecast for ownerships or number of conventional cars and didn't consider other influential factors while forecasting, e.g. incentives, availability of models and brands, public awareness.

The increase of EV market share depends on more factors than the conventional car or the market of ICE vehicle does because electric vehicle is a technological innovation (Aksen & Kurani, 2012) and a recent phenomenon. Sierzchula et al., (2014) analyzed how several socio-economic factors and financial incentives influences electric vehicle adoption. The modeling for EV market share (EVMS) is presented in Eq. (4) below. Most importantly, this EV market share (EVMS) model is not to predict or forecast the electric vehicle numbers rather this model emphasizes on how the market share of electric vehicle can be increased or accelerate by adopting different electric vehicle policy measures.

$$EVMS = \alpha + \beta_1 P + \beta_2 U + \beta_3 W + \beta_4 I + \beta_5 C + \beta_6 A + \varepsilon \quad (4)$$

Where,

EVMS = Expected EV market share

α = Intercept (market share without influence of the policy measures: P, U, W, I, C, A)

β_i = coefficients of the variables or policy measures, where $\beta_i > 0$ and $i = \{1, 2, \dots, 6\}$

ε = Random error (other random factors that influences the market share)

P = Electric vehicle **P**urchase incentives

U = Electric vehicle **U**se incentives

W = **W**aivers on access restrictions

I = Charging **I**nfrastructures (Publicly Accessible)

C= Communication process and **A** = **A**vailability of different EV brands

EVMS model can help the decision makers to control the EV market shares by adopting different policy measures based on their affordability, national transport system, and readiness. However, it is necessary to keep balance among different type of enforced policy measures for constant growth in market share. For instance, investing only in EV purchase

incentives can increase the EV market share up to a certain point and to continue the increase of market share constantly the investment in building charging infrastructures is also needed. It is important because, the increased number of EVs will require more charging infrastructures for charging. Furthermore, to attract the mass population there should be activities to let people be knowledgeable about all the aspects of EVs and there should be enough EV brands available in the market to give buyers more options and to convince growing number of buyers. It will be advantageous as well to introduce electric vehicle use incentives and allowing the EV buyers some extra access in traffic regulations. Therefore, to some extent all of the policy measures included in Eq. 4 is necessary in keeping constant growth in EV market share. Using EVMS model decision makers can estimate what will be the possible change in EV market share if they want to invest in certain policy measures, holding all other variables constant.

Even though China's large investment in NEV projects results rapid growth of NEV numbers, from section 2.5 (comparison between policies) it is understandable that China's NEV policies may consider some constructive changes, e.g., besides the high price tag on EVs, China consumers are not enough knowledgeable and aware about EV related issues (including its policy measures) and they are not enough satisfied with the brand, model options they have in the market. Thus, holding other variables (economic, social political variables) constant, if China would focus more on these policy measures, the market share of EV would be even more than what it has now and that can lead to reach their set target. EVMS model can be used by decision makers from any country.

In Eq. 4, charging infrastructure, communication process or public awareness and availability of EV brands are considered as supporting EV policy measures. Here, the communication or public awareness defines the communication to make car buyers aware about the policy measures and to provide practical information about electric vehicle cars which can influence the buying decisions of the car buyers. Availability of electric vehicle (EV) brands represents the market that provides best available model from different EV brands to the buyers/consumers to make their buying decision. Countries can make their taxes schemes flexible, and provide some extra corporation facilities to both local and foreign EV manufacturers to welcome different EV brands.

Along with the discussion on comparison between EV policy measures of Norway and China, the previous studies, research results, journal publications also support the development of

EVMS model. Fig. 6.1 shows that most of the countries are still in innovator stage and economy of large-scale energy vehicle transition theory explained in Fig. 3.4 demonstrates the necessity and effectiveness of purchase incentive, P, for widespread EV adaptation. Moreover, the factors influencing the travel transport demand explained by Button (2014) also assert the importance of EV price and demand relation. Generalized cost notion by Mathisen (2008) and table. 5.1, 5.2 (in Chapter 5) illustrate the importance of Electric vehicle use incentives, U, and waivers on access restrictions, W. Rogers (1983) Innovation decision process and table 5.5 (in Chapter 5) emphasize the effectiveness and efficiency of communication process or public awareness, C. The importance variable, A, can be described from fig. 3.3 where taste can be resembled with model and brand availability of EVs. Moreover, Chinese car buyers' preference of brands described in section 2.5.4 (iii) also supports the presence of the policy measures, A, in Eq. 4. The descriptive discussion from section 2.5.4 (i) and as per information in table 5.2, 5.3 (in Chapter 5) electric vehicle charging Infrastructure, I, stands as one of the most important factor that can influence the widespread electric vehicle adoption. Table 2.8 summarizes the importance of purchase incentives, P, use incentives, U, and waiver on access restriction, W, which is also necessary to take into consideration in order to illustrate the influence of these policy measures on EV market shares.

The significance of electric charging infrastructures, I, purchase incentives, P, use incentives, U, and waivers on access restrictions, W, in EV market share is described in more detail in the later part of the research with numerical value evidence and quantitative techniques. The parameter or coefficient of most of the variables β_1 - β_4 of Eq. (4) are already obtainable, only the coefficient for variable C and A are not measured due to the lack of insufficient data. Therefore, this research analysis does not include the quantitative impact of these two variables on EV market share but descriptive evidences. Furthermore, causal effect of policy measures C and A on EV market share is explainable by critical realism and generative theory for causation.

The value of β_1 - β_6 can be calculated in two ways. In one way, the value can be calculated based on global data (or different major EV markets' data) where the value will be considered as standard for all EV markets. In this research for further analysis the value of β_1 - β_2 taken from Sierzechula et al., (2014) where the coefficients were measured based on different major EV markets' available data. In other way, to be more specific for any specific

country, the value of $\beta_1-\beta_6$ can be calculated based on that specific country's available data, e.g. to understand the effect of electric vehicle charging infrastructures specifically on US market, regression analysis has been done (section 6.5).

3.5 Statistical models

3.5.1 Forecasting Model

Hyndman and Athanasopoulos (2012) defines that forecast is a statistical technique about predicting the future as accurately as possible, given all of the necessary and relevant information available, including historical data and information of any future events that might influence the forecast results. Forecasting or predictability of any event depends on several important elements, including: 1) understanding of the factors that influencing forecasting, 2) the availability of data and 3) the likelihood that the forecast can affect the thing that we are trying to forecast (Hyndman and Athanasopoulos, 2012).

In this research, the forecasting item, sales of conventional passenger cars in any given country, satisfies all the elements described by Hyndman and Athanasopoulos (2012). The forecasting of sales of conventional passenger cars in any given country depends on several factors but most important factors are GDP and population growth of that given country. The data for forecasting of sales of conventional passenger cars are also usually available and forecasting doesn't affect the sales of conventional passenger cars. According to description given by Hyndman and Athanasopoulos (2012), our forecasting falls into quantitative forecasting category as the numerical data of past several years' sales of conventional passenger cars (ICE Vehicles) in China is available and it is reasonable to assume that some aspects of the past pattern will continue in future.

Unger (2015) uses random walk model⁶ with drift to predict the number of total vehicle-in-use which can be considered as a limiting case of first-order Autoregressive⁷, AR (1) model. Nau (2017) recommends that if the non-seasonal time series is stationary and auto-correlated then the forecasting can be conducted using first-order Autoregressive, AR (1) model. But if

⁶ Another way to express random walk model is Auto-regressive Integrated Moving Average, ARIMA (0, 1, 0). Random walk model can be with drift and without drift.

⁷ The first-order autoregressive, AR (1) model can be expressed as ARIMA (1, 0, 0). A non-seasonal ARIMA model is classified as an "ARIMA (p,d,q)" model, where: p is the number of autoregressive terms, d is the number of non-seasonal differences needed for stationarity, and q is the number of lagged forecast errors in the prediction equation. (Nau, 2017)

the non-seasonal time series is not stationary then it's appropriate to conduct forecasting by using random walk model with drift.

The forecast equation for the number of conventional passenger cars (ICE Vehicles) from 2017 to 2035 by using random walk model with draft can be written as:

$$V_t = \mu + V_{t-1} \quad (5)$$

V_t = Estimated number of conventional passenger cars in year t

V_{t-1} = Number of conventional passenger cars in year t-1

μ = Constant term is the average period-to-period change in V.

Nau (2017) suggests that this model can be fitted as a no-intercept regression model in which the first difference of the number conventional passenger cars, V (V lagged by one period) is the dependent variable. This model includes non-seasonal difference and a constant term, and this it is classified as random walk model with drift. More detail has been described in section 4.5

It needs to be noted that the prediction or forecast intervals for t (=2030...2035...2040) widens as we attempt to forecast farther into future. Usually, the farther into the future we conduct forecast the less certain or confident we are of the accuracy or preciseness of the forecast because some unforeseen changes or states in business and economic conditions make may make the model inappropriate; which means that we will have less confidence in the forecast for, say, t=2035 than for t=2030, it follows that the prediction or forecast interval for t = 2035 must be wider to attain a 95% level of confidence. Therefore, time series forecasting (regardless of forecasting method) is generally appropriate to the short term. (Mendenhall & Sincich, 2012)

According to Unger (2015), after forecasting the number of conventional passenger cars (ICE Vehicles), the number of electric vehicles (EVs) can be forecasted based on the market share of electric vehicles (EVs). The market share of EVs calculated using the Eq. 4, $[EVMS = \alpha + \beta_1 P + \beta_2 U + \beta_3 W + \beta_4 I + \beta_5 C + \beta_6 A + \epsilon]$. Denoting the market share of electric vehicles in year t as δ_t .

So, the number of electric vehicles (EVs) in year t, will be

$$EV_t = V_t * \delta_t \quad (6)$$

Here,

EV_t = Estimated sale of electric vehicles in year t

V_t = Estimated number of conventional passenger cars in year t

δ_t = Market share of electric vehicle at t (t = 2017, 2018...2022), $\delta_t > 0$

3.5.2 Measurement of magnitude of the consequence of the crude oil demand

Unger (2015) suggests that electric vehicles only affect crude oil demand through the fuel consumption. The regression results or coefficient of the impact of total vehicle-in-use on global fuel consumption and the impact of global fuel consumption on global crude oil demand from Unger (2015) analysis are used in this research analysis to calculate the magnitude of the consequence of the crude oil demand in China by adopting Norwegian EV policy.

Denoting,

The coefficient or parameter of the impact of vehicle-in-use on fuel consumption by κ ,

where, $\kappa > 0$ and

The coefficient or parameter of the impact of fuel consumption on crude oil demand by ρ ,

where, $\rho > 0$

Therefore, the estimated reduction of fuel consumption in year t, F_t , as a result of electric vehicles (EVs) in China, can be describe as

$$F_t = EV_t * \kappa \quad (7)$$

Then, the estimated reduction of crude oil demand in year t, C_t , in China can be described as

$$C_t = F_t * \rho \quad (8)$$

The chain-effect of electric vehicle on crude oil demand can be summarized by the following fig. 3.5. Electric vehicle directly affect the fuel consumption, F_t , and fuel consumption affects the crude oil demand, C_t , because fuel, e.g. petrol, is produced out of crude oil.

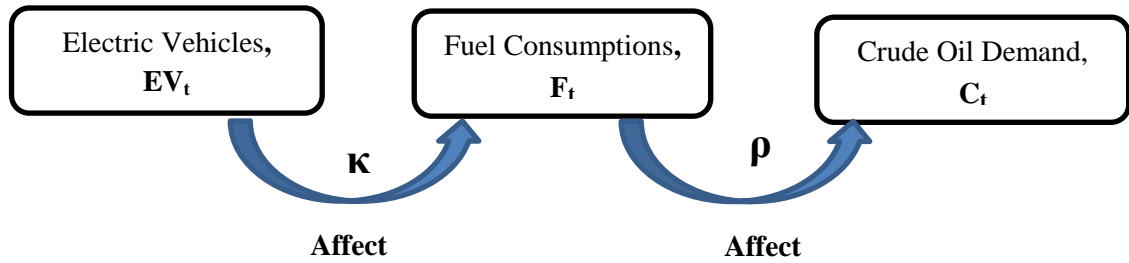


Figure 3.5: How Electric vehicle impacts the crude oil demand

Chapter 4: Methodology

This chapter describes the methodological basis for the thesis and explains how the empirical data gathered for analysis purposes. The thesis comprises both descriptive and numerical parts with quantitative analysis techniques. This chapter starts with a brief description of scientific positioning of research methods. Thereafter, brief discussion of secondary data and statistical methods are accounted for.

4.1 Research philosophy

Easterby-Smith et al., (2012) describe research philosophy is very useful for three reasons: 1) It can help to clarify research design, 2) It can help to recognize which research design will work and which research design will not work, 3) It can help to identify, even create research design that may be different from the researcher's past experience.

The most central philosophical debate among the scientists and social scientists is concerned about the ontology and epistemology when developing research methodologies. Easterby-Smith et al., (2012) defines Ontology is philosophical assumption about the nature of reality while Epistemology refers to the set of best ways enquiring into the nature of the physical and social worlds. Ontology philosophical assumption can be described from four different positions: realism, internal realism, relativism and nominalism (tab. 4.1)

Table 4.1: Four different Ontologies; *Source; Easterby-Smith et al., (2012)*

Ontology	Realism	Internal Realism	Relativism	Nominalism
Truth	Single truth	Truth is obscure but truth exists	Many truths exists	There is no truth
Facts	Facts can be revealed	Facts cannot be accessed directly	Facts depends on the view point of the observers	Facts are all human creation

On the other hand, according to Epistemology philosophy social scientists have two contrasting views of how social science research should be conducted: social constructionism and positivism. According to the description of Easterby-Smith et al., (2012), social constructionism is a new paradigm that emphasizes on the ways that people make sense of the world especially through sharing their experiences while positivism asserts that reality exists externally and its existence can be measured through objective methods. Social

constructionism urges that social scientists should focus on the different constructions and meanings from people's different experiences rather than collecting facts and measuring the reality based on those collected facts.

4.1.1 Positivism

Positivism is considered one of the appropriate ways to investigate human and social behavior. Keat and Urry, (2011) suggests that in positivism knowledge is obtained through observations and only observation provides logical foundations for scientific theorizing. In positivism, research findings are usually quantifiable and observable. Easterby-Smith et al., (2012) describes the philosophical assumptions of positivism:

- In positivism, the observer is independent from study or what is being observed.
- Objective criteria determine what to study and how to study, not the human beliefs or interest.
- The regularities in human social behavior are explained by identifying the causal explanation and fundamental laws.
- Facts need to be measured quantitatively. Positivism relies on quantifiable observations and thus statistical analysis is required in positivism.
- Reductionism: Problems are better understood if they can be reduced into simplest possible elements.
- In order to generalize anything specific, it is necessary to select random samples which can represent the wider population.

4.1.2 Linking Ontology, Epistemology and Methodology

Easterby-Smith et al., (2012) suggests that depending on both research enquiry and individual researcher's own preferences, it can be evaluated if the assumption and methods of natural science are appropriate to be used in the social science. There is a neighboring link between epistemology and ontology. Tab. 4.2 summarizes that positivism and social constructionism are connected to internal realist and relativist ontologies respectively while strong positivism and strong social constructionism interconnected with realist and nominalist ontologies respectively. The relevant methodologies under the four philosophical positions are also summarized in Tab. 4.2. There are differences between the stronger and more normal version of positivism and constructionism. In brief, the strong constructionism assumes that individual and social knowledge are indifferent whereas normal or less strong constructionism accepts the existence of independent and objective knowledge while

constructing own knowledge. The normal or less strong positivism assumes that reality cannot be accessed directly and data is usually expressed in quantitative form but can be supplemented by qualitative data. In less strong positivism, patterns and regularities in behavior are identified and thus less strong positivism allows proposition tests in order to develop new ideas. On the other hand, strong positivism position assumes reality exists independently and researchers are required to discover laws and theories to explain the reality.

Table 4.2
Methodology implications of different epistemologies

Ontologies	Realism	Internal Realism	Relativism	Nominalism
Epistemology Methodology	Strong Positivism	Positivism	Constructionism	Strong Constructionism
Aims	Discovery	Exposure	Convergence	Invention
Starting points	Hypothesis	Propositions	Questions	Critique
Data types	Numbers & facts	Numbers & words	Words & numbers	Discourse & experiences
Analysis	Verification	Correlation & regression	Triangulation & comparison	Sense-making understanding
Outcomes	Confirmation of theories	Theory testing and generation	Theory generation	New Insights an actions

Source; Easterby-Smith et al., (2012)

4.1.3 Critical Realism

Archer et al. (2016) defines “Critical realism is a series of philosophical positions on a range of matters including ontology, causation, structure, persons, and forms of explanation” (Archer, et al., 2016)

In critical realism, causality exists as potential, in contrast to the correlation of the events that is usually associated with strong positivism. Easterby-Smith et al., (2012) mentions that critical realism provides compromise position between strong positivism and strong constructionism. Critical realism starts with realist ontology which recognizes social conditions have real consequences irrespective of the fact whether they are observed or unobserved and then incorporates a relativist thread which recognizes that both the actions of individual and external impact on them generate social life. Little (2013) asserts that critical realism is the familiar position of scientific realism in applied social sciences.

4.1.4 Scientific Realism (Philosophy for quantitative research)

Haig (2013) asserts that scientific realism is the dominant philosophy of science today and it is the tacit philosophy of most working scientist. Haig (2013) argues that positivism is limited to only what can be observed and excludes the unobservable features. Positivism considers theories as instrument that establish claims about observables features but that do not explain them by appeal to hidden causes. On the other hand, scientific realism is loyal to at least two main doctrines: 1) we all are part of a real world, and 2) the world possesses both observable and unobservable features and those observable and unobservable features can be known or discovered by the proper use of scientific methods. In contrast to positivist view, the scientific realist emphasize on the causal explanations of the occurrence of events instead of establishing the logical necessity between phenomenon and logic. The scientific realist realizes the relations of "natural" necessity that exist in the physical world (Keat & Urry, 2011).

Scientific realism got its momentum from the theoretical concepts generated from physical theories that are not themselves directly observational – moun, an elementary particle similar to the electron. Though the essence of scientific realism is related with esoteric physical theory, Little (2008) demonstrates that in different specific ways scientific realism is useful in social science. Little (2008) asserts that it is feasible to consider social realist perspective on many theories of social science which means that social science statements can be interpreted as being approximately true of a domain of social phenomena that possess objective properties.

Scientific realist methodology includes a wide variety of methods; explanatory data analysis, statistical significance testing, Bayesian confirmation theory, meta-analysis, exploratory factor analysis and causal modeling.

4.1.4.1 Causal modeling method

Causal modeling method is a statistical method developed by social and behavioral science methodologists to help to draw causal conclusion from correlational data. Causal modeling methods include three elements: path analysis, confirmatory factor analysis and full structural equation modeling. Furthermore, according to causal modeling, researchers need to satisfy three conditions to establish that one variable is the cause of another variable: 1) the relationship between variables is asymmetric, and 2) the presence of functional relationship between cause and effect, 3) the causal relationship is direct and non-spurious. These three

conditions of causal relationship are exactly extracted from the regularity theory. (Haig, 2013)

However, Haig (2013) claims regularity theory has strong criticism and the claimed limitations of regularity theory can be appreciated by contrasting it with a scientific realist alternative. The scientific realist alternative is known as generative theory of causation.

4.1.4.2 Generative Theory of Causation

Haig (2013) defines that generative theory represents causation as a relationship variables where causal mechanism produces its effect or causal relationship under appropriate conditions, which means that in order to establish a causal relationship between variables, the causal mechanism must be associated to its effect and must have the power to produce that effect, usually when triggered by appropriate casual condition. In generative theory of causation, the causal power exists regardless of whether the causal power currently being exercised. Thus, generative theory views the causal power also as a tendency that is existing state of an object and once it is unimpeded or exposed, it will produce the effect. Therefore, the presence of the causal mechanism can be concluded on the basis of knowledge of the triggering condition and/or its presumed effect. One related advantage of the generative theory is that it is necessary for progressive social policy, as more satisfactory or improved actions depend on possible affecting change. The possible affecting changes can be evaluated based on an understanding of how things work, and for this, knowledge of relevant underlying causal mechanism is often essential.

4.1.5 Neoclassic Research Paradigm

Transport economics is application of microeconomic theories which is based on positivist neoclassic model. The most eminent aspect of neoclassic theory is its assumption on marginal components, e.g. marginal costs and marginal revenue. Maximization of utility and profit are also important component of neoclassic theory. Holding all other market mechanism constant, the only instrument to influence market is price. By description of Klette (1989), Mathisen (2015) mentions the core assumptions of the neoclassic research theories: 1) All market participants are maximizing their utilizing, 2) All market participants are perfectly informed about the factors that influence their utility and based on the information the participants are maximizing profit, 3) The price level is determined by the supply and demand exists in the market, 4) there is alternative cost of everything and 6) simplified models are effective for better economic analysis. (Mathisen, 2005)

Utility in economics refers to measurement of satisfaction obtained from a commodity or service. Though neoclassic research theories include profit maximization, Mathisen (2015) suggests that the assumption of profit maximization is not necessarily true for transport market. Jørgensen and Pedersen (2004) discovered that private foreign owners are usually more profit focused while local public owners are more focused towards welfare maximization. In transport economics, both stated preference and revealed preference makes the utility function. Stated preference refers to the techniques where people decide how much they are willing to pay to obtain something while revealed preference gives choice between two different outcomes making it possible to reveal preferences indirectly. Mathisen (2015) argued that characteristics of transport market make it reasonable for market participants on the supply side to maximize the utility function instead of profit.

4.2 Philosophical positioning of the research

In this thesis, the required analysis to answer the research question suggests for choosing quantitative approach that is supplemented by descriptive discussion and analysis. The research problem is measuring the magnitude of the changes in crude oil demand by adopting Norwegian EV policy from the evidence of China's current electric vehicle (EV) market and new energy vehicle (NEV) policy measures. This research assumes a measurable reality and research data are analyzed through numerical comparisons, statistical inferences which fall into the characteristics of quantitative analysis.

This research mostly follows the positivism assumptions. What is being observed in this research is left independent from the observer. The research design satisfies the value-freedom assumption; the objective criterion of this thesis has decided what to study and how to study and it excludes human beliefs. Alike positivism, the relation between different EV policy measures and EV market shares satisfies the causality explanation and most facts or assumed realities in the research analysis are measured quantitatively.

From table 4.2 views, this research work falls under the column where internal realism and positivism are linked. Thus, this research work can be described from different philosophical perspectives. Moreover, this research work can be also described from critical realism perspective as critical realism deals with casualty as well as both observed and unobserved social conditions. The causal relation of variables (e.g. communication process and availability of different brands) with EV market share can also be realized from critical realism (unobserved) perspective.

On the other hand, from the philosophy of quantitative research or scientific realism, this research analysis approach imitates the causal modeling method. The EVMS model (Eq. 4) that has been developed for EV market shares adoption is based on the causal relationship, e.g. \$1000 increase in purchase incentive or 1 unit charging infrastructure installation can cause increase of the EV market share. EV market share has same causal relationship with other variables of Eq. 4. The cause-effect relations (with EV market share) of two variables, communication process and availability of different brands, can be explained by generative theory of causation because these two variables are not yet exercised but they have tendency to produce effect. The presence of causal mechanism of communication process and availability of different brands can be explained on the basis of the knowledge from chapter of theoretical framework, comparison between EV policies and data from chapter of empirical data.

Moreover, the impact of EVs on fuel consumption and the impact of fuel consumption on crude oil demand – in both cases, the relations between variables are casual relationships, e.g. the increase number of electric vehicle impacts the fuel consumption by a certain quantity and that changes in fuel consumption also influence the crude oil demand by certain quantity.

To measure the EV market share we discussed and analyzed the EV incentives and policies to make the EV prices competitive compared to conventional vehicles and maximize the utility for the buyers which follow the utility function of transport economics. Thus, the theoretical frameworks and analysis can also be explained from neoclassic research paradigm.

4.3 Research Process

The thorough process or analysis that is carried out to answer the research question can be explained by following way:

- **Establishing basis (Chapter 2):** Firstly the fields of study - Electric vehicles (EVs), Norwegian EV policy measures and New Energy vehicle (NEV) policy of China and the connection between crude oil and transportation were described briefly. In the later of this part (section 2.5), the comparison between Norwegian EV policy and NEV policy of China is done based on data and evidence from different sources, e.g. previous studies, reports, journal publications. This part actually establishes the basis for later chapters.
- **Establishing theoretical framework for analysis (Chapter 3):** Relevant theoretical framework is established (section 3.1-3.3) and at the end of this part, a modeling for EV

market share (EVMS), Eq. 4, is created based on theoretical framework (section 3.1 -3.3) and descriptive analysis in Chapter 2.

- **Empirical data to conduct analysis (Chapter 4):** The necessary empirical data to answer the research question elaborately described in this chapter. In section 5.4, the modeling designed in Chapter 3 (Eq. 4) is validated with empirical data from different authentic sources.
- **Analysis based on theoretical framework and empirical data (Chapter 6):** At the beginning of Chapter 6, the necessity of changing NEV policy is justified based on the studies in Chapters 2, 3 and 5. In section 6.3, analyzing has been conducted to quantify the possible market share changes based on generated model EVMS and empirical data. Finally, in section 6.4 the answer for the research question has been calculated based on the quantitative techniques.

4.4 Data collection

Common classification of data is based upon who collected the data; primary data and secondary data. Usually if the data set is collected by the researcher or a team of which the researcher is a part for any specific purpose or analysis then it is called primary data while if the data set is collected by someone else for some other purpose, it is called secondary data (Boslaugh, 2007).

Easterby-Smith et al., 2012 suggests that secondary data sources can include company or government reports, advertisements, newspaper articles, archival data, books, websites and data banks. Easterby-Smith et al., 2012 also mentioned several advantages of secondary data: 1) secondary data saves time and effort for the researchers, 2) if the data is published by companies and governments then the data sources are considered as high quality sources, 3) Historical perspective can be achieved from secondary sources. (Easterby-Smith et al., 2012)

According to the definition of Easterby-Smith et al., (2012) and Boslaugh (2007), the data set in my thesis falls into secondary data category. To answer the research question, firstly, I required knowledge and authentic demonstrations of the EV policies especially about Norwegian and Chinese to establish constructive differences between the two EV policies and to generate appropriate model for EV adoption. Finally, I required quantitative data to measure the magnitude of market share changes and consequences for crude oil demand. All the required theories, descriptive and quantitative data I have collected from different authentic sources, such as journals publications, archives, books, organization and

government reports, newspaper articles and websites etc. The key sources for key data for this research analysis are illustrated in table 4.3.

Table 4.3
List of key sources for key data used for this research

Key Data	Key Sources
Norwegian EV policy	Haugneland et al.,(2016), Norsk ebilforening, Figenbaum et al., (2015), Fearnley et al., (2015)
China New Energy Vehicle (NEV) Policy	ICCT (2013), Yang et al.,(2016), An (2016), Innovation Center for Energy and Transportation (iCET, 2016), Zheng et al., (2012), Zhang et al., (2011)
Statistics on EV market share, Number of new EV registrations, EV stocks, EVSE stocks, annual Installation of EVSEs	International Energy Agency (IEA, 2016), PricewaterhouseCoopers (pwc.com), International Council of Clean Transport (ICCT.org), Sierzchula et al., (2014)
Statistics on Passenger Car	Statistisk sentralbyrå (ssb.no), statista.com, theglobaleconomy.com, Organisation International des Constructeurs d'Automobiles (oica.net), China Statistics Press, 2017, Dargay et al.,(2007), Wang et al., (2012)
Population	China Statistics Press (2017), Statistisk sentralbyrå (ssb.no), The world bank , 2017 (worldbank.org)
Statistics on oil consumption	globalpetrolprice.com, BP statistical review of world energy (2016), BP energy outlook (2016), World energy outlook (2011)

The Coefficients or parameters of the independent variables used in this research analysis are collected from previous journal publications and studies (table 4.4).

Table 4.4
Sources of Coefficients or parameters of different variables

Variable	Coefficient	Sources
Electric vehicle Purchase incentives (P)	β_1	Sierzchula et al., (2014)
Electric vehicle Use incentives (U)	β_2	Fearnley et al., (2015)
Waivers on access restrictions (W)	β_3	Fearnley et al., (2015)
Charging Infrastructures (I)	β_4	Sierzchula et al., (2014)
Impact of vehicles-in-use on fuel consumption, (F)	κ	Unger (2015)
Impact of fuel consumption on crude oil demand, (C)	ρ	Unger (2015)

The data of conventional passenger car sales in China from 2005 to 2015 which is used to forecast the number of conventional passenger cars from 2017 to 2040 falls into the time series data category. Mendenhall and Sincich (2012, p. 519) defines “time series is a collection of data obtained by observing a response variable at periodic points in time and If repeated observations on a variable produce a time series, the variable is called a time series variable”. Hyndman and Athanasopoulos (2012) suggest that time series data are useful input when forecasting something that is changing over time.

4.5 Autoregressive Integrated Moving Average (ARIMA) model

Nau (2017) defines ARIMA (p,d,q) models as the most general model for conducting forecast of a time series data which is stationary or if necessary can be made to be stationary by differencing, possibly in conjunction with nonlinear transformations, e.g. logging or deflating. Autoregressive term, p, refers to the lags of the stationarized time series in the forecasting equation while the time series which is not stationary but needs to be differentiated in order to make the series into stationary is referred as integrated, d, version of stationary series, and finally the moving average, q, refers to the lags of the forecast errors. Central ARIMA models are autoregressive models, random walk model and exponential smoothing model.

The historic data on sales of China’s conventional passenger cars from 2005-2015 is not stationary but possess long period apparent trends and also there are sudden, unpredictable

changes in directions observable. Thus, the data set of China’s conventional passenger cars (ICE vehicles) from 2005-2015 falls into the random walk theory (Hyndman & Athanasopoulos, 2012).

There are other reasons of choosing random walk model or ARIMA (0, 1, 0) model for forecasting the number of conventional passenger cars (ICE vehicles): Fig. 4.1 illustrates that the differences (lagged by one period) between years are random, not consistent. The result of SPSS descriptive statistics shows differences (lagged by one period) has smaller standard deviation than data set, which also suggest that the data set from 2005-2015 is not stationary.

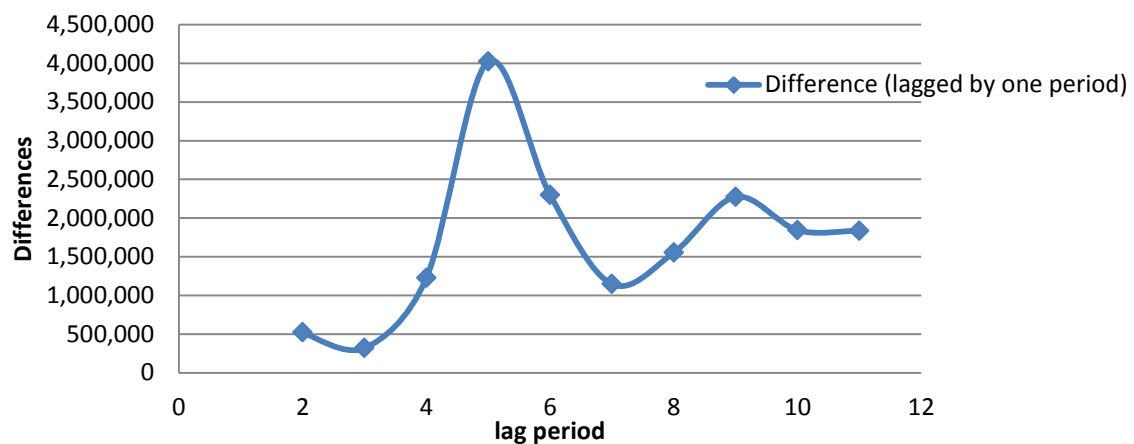


Figure 4.1: Differences (lagged by one period) between years of the data set of China’s conventional passenger cars, 2005-2015;

Moreover, autocorrelation analysis is made (fig. 4.2). The analysis shows the differences (lagged by one period) of the data set are not correlated and insignificant. Thus, fig 4.1-4.2 illustrates that the data set of China’s conventional passenger cars (ICE vehicles) is non-stationary and therefore, random walk model or ARIMA (0, 1, 0) model is best fitted for forecasting the number of passenger cars in China from 2017-2035.

Differences					
Autocorrelations					
Series: Differences					
Lag	Autocorrelation	Std. Error ^a	Box-Ljung Statistic		
			Value	df	Sig. ^b
1	-.089	.284	.097	1	.755
2	-.531	.266	4.081	2	.130
3	-.001	.246	4.081	3	.253
4	.252	.225	5.342	4	.254
5	-.066	.201	5.449	5	.364
6	-.077	.174	5.642	6	.465
7	.006	.142	5.643	7	.582

a. The underlying process assumed is independence (white noise).

b. Based on the asymptotic chi-square approximation.

Figure 4.2: Autocorrelation analysis between the differences (lagged by one period) of data set China’s conventional passenger cars, 2015-2015

The data set of conventional passenger car (ICE Vehicles) of China and world-wide from 2005-2015 is shown in table 5.1 and detail figures are shown in Appendix 1. The analysis has been done by both Microsoft Excel and SPSS software.

4.6 Regression Analysis

Generally, a regression analysis is used for one or more of three purposes: (1) prediction or forecasting of dependent variables, (2) modeling the relationship between variables independent variable, x and dependent variable, y, and (3) testing of hypotheses (Simonof, 2016). In this research, I have used regression for modeling the relationship between x (independent variable) and y (dependent variable).

In linear model, if we have n sets of observations $\{(X_i, Y_i), i= 1,2,...n\}$ which represent a random sample from large population, then these observation satisfy a linear relationship.

$$y_i = \alpha + \beta_1 x_i + \varepsilon_i \quad (9) \quad (\text{Wooldridge, 2012})$$

Here, β is coefficient or parameter, and the ε_i is random error terms. Linear model represents the model which is linear in the parameters. A positive value of β demonstrates direct relationship between y (dependent variable) and x (Independent variable), e.g., higher

demand of EVs (y) is associated with higher value of purchase incentives (x). On the other hand, negative value of β demonstrates inverse relationship between dependent and independent variables, e.g., higher price of EVs (x) leads toward lower demand of EVs (y)

The parameters of independent variables in Eq. 4 are calculated using regression model where, $X_i = \{P, U, W, I, C, A\}$. The parameters or coefficients (e.g. $\beta_1, \beta_2, \beta_3, \beta_4, \rho, \kappa$) used in this research analysis are results of regression analyses done by respective researchers. In this research, to measure the relationship between charging infrastructure, I , and EV market share, EVMS, specifically in US EV market (section 6.5), I have used linear regression model. Thus, the relationship between variable (policy measures) and EV market share, EVMS, for specific countries can be measured by conducting regression analysis. The parameter, κ and ρ from Eq. 7 and Eq. 8 respectively are also calculated by conducting regression analysis by Unger (2015).

Ordinary least squared (OLS) or simple linear regression (SLR) follows set of five assumptions (Wooldridge, 2012). If we consider Eq. 9 as standard for all the regression analysis used in this research analysis, then it needs to mention that the Eq. 9 fulfills the assumptions to be considered as SLR. The first assumption is that variables, y , x and ε in Eq. 9 are all viewed as random variables. Secondly, the data were collected on random sample basis. According to third assumption, sample outcomes on x from Eq. 9, namely, $\{X_i, i= 1, 2, 3 \dots n\}$, are all different values which is there are sample variations in the explanatory variables. Forth assumption states that the error, ε , from Eq. 9 has an expected value of zero. The fifth assumption is concern with variance of ε and states that the variance of ε , conditional on x , is constant.

4.7 Reliability and Validity

I. Reliability

Reliability refers to the repeatability of research findings, or in other words, the purpose of checking reliability is to make sure that exactly same results will be achieved if any researcher performs the exactly the same research analysis later on. However, the requirement for this is that same methodology, assumptions are needed to be used under same conditions. The reliability of data obtained also affects the research analysis. Here, need to be mention that, for this research purpose, the numbers of new electric vehicle sales per years in China is obtained from IEA (2016) which can be considered authentic sources of information for electric vehicles. But according to Schmitt (2016), China's central government fraud

investigation reports suggests that car manufacturers sell poor-quality vehicles to their own car rental companies which exists only to obtain the subsidies from government and even there have been reports of alleged plug-in vehicles which never are plugged-in (Schmitt, 2016). Moreover, as already mentioned in section 2.3 that originally, in China simple hybrid cars were also part of the electric vehicle definition and later in 2013, China excludes the simple hybrid cars from subsidy policies but no authentic source still never can assure if hybrid cars are still selling as electric vehicles in China (Schmitt, 2016). Therefore, the sales volume of electric vehicles in China can be little bit different in different sources. As there is no available better source to clarify which is exact sales numbers I considered data from IEA (2016) as reliable and used for analysis purposes.

The regression results or coefficient values are likely to be same if same data and source is used. But here, also need to be mentioned that the recently the changes and growth in electric vehicles market is very rapid and large that the results of analysis can be little bit different based on time series length. Hence, if similar study uses the same methods, assumptions and data, it would most likely to reproduce the same finding.

II. Validity

Alike reliability, the principle of validity is another fundamental cornerstone of scientific method. The validity of a research can be divided into internal and external validity (Easterby-Smith et al., 2012). Internal Validity explains if a research design is structured and includes all necessary steps of the scientific research method and thus explains if the findings provide appropriate representation of the descriptions. Campbell and Stanley (1966, p.5) defines that “Internal validity is the basic minimum without which any experiment is uninterpretable: Did in fact the experimental treatments make a difference in this specific experimental instance?”

In this research analysis, I have used wide-ranging theoretical frameworks, quantitative methods and systematic approach for providing concrete evidences and analyzing the research areas from different relevant perspectives and therefore, it gives me confidence that the analysis and conclusions are accurate. In research design, it has been described that how systematic and with proper evidence every chapter is organized. The concept of electric vehicle is not new but latest uplift of electric vehicle has happened only few years back and as a result, there are still lacks of proper information and in few cases there is no sufficient amount of data to conduct few analysis, e.g. there is only 4-5 years data available on the sales

of electric cars and charging infrastructure in China as the revolution of electric cars in China happened very recently. Therefore I had to narrow down the analysis in one case (measuring the coefficient of charging infrastructure only for USA, not China, section 6.5). I have also taken proper cautions in cases where I have to make assumptions to conduct the research analysis (e.g. according to IEA (2016), policies such as road toll, ferry fee exemption, free parking and bus lane access for EVs are nationwide implemented only in Norway. Therefore, the effects of these policies on EV market share in Norway are considered as standard while calculating changes of EV market share in China by adopting similar Norwegian EV policy.

According to Campbell and Stanley (1966, p.5), “External validity asks the question of generalizability: To what populations, settings, treatment variables and measurement variables can this effect be generalized?”

The characteristics of EV market differ from other automobile markets. But the modification (if necessary) of the modeling (EVMS), that is developed for EV adoption, can be applied to other innovative automobile market, such as autonomous car market. Especially, the policy measures of communication process and availability of different brands can be considered important to increase market share for any type of innovative automobile market.

Chapter 5: Empirical data

The aim of this Chapter is to present the relevant empirical findings derived from the data collected by using theoretical framework as the main lead for searching data. This chapter starts with the explanation of the significance of China automotive market which is followed by discussion on the EV market differences between Norway and China. The reasons behind the differences of these two EV markets are described based on the studies of Chapter 2. Thereafter, the impact of different EV policy measures (P, U, W, I, C, A) on market share is provided. Discussion on parameters for fuel consumption and crude oil demand conclude this Chapter.

5.1 The magnitude of automotive market in China

China has remained as the world's largest auto market for last few years; the pace of the growth is relentless. The growth of passenger car sale in China is higher than rest of the world even though the growth slowed in 2014-2015 compared to 2013 growth (fig. 5.1). The passenger car year-over-year sales growth for the rest of the world was below zero (negative growth in 2015) while China had year-over-year sale growth of 7.3% in 2015. In 2013, it had highest year-over-year sale growth (15.7%) in last five years (2011-2015). The importance of China auto market can be magnified from the statement of Yale Zhang, managing director at researcher Automotive Foresight (Shanghai) Co Ltd. "China is a vital market for automakers around the world and policy uncertainties here are the biggest challenge for those counting on this demand" (Ying, 2016). Automakers have massive investment in emerging market countries, particularly in China. Hirsh et al. (2016) suggests that smart joint ventures with Chinese companies would facilitate to achieve increased and consistent return taking advantage of the potential vehicle sales growth but for that automakers should be able to manage production of more profitable, pricier models.

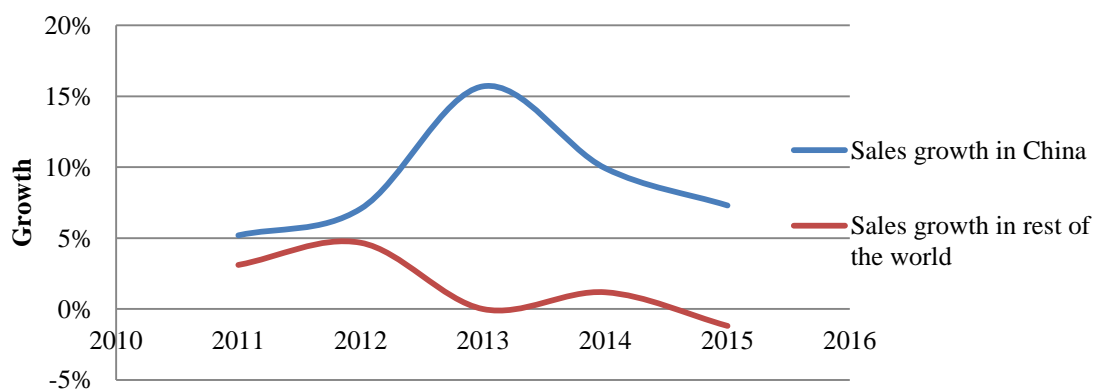


Figure 5.1: Sales growth comparison between china and rest of the world: *Source:*

Oica.net

Tab. 5.1 and fig. 5.2 illustrates the size of China auto market. Tab. 5.1 shows that for last 4 years (2012-2015) China accounts for more than one fourth of the total passenger car sales in the world. In 2015, the increased global sale of passenger cars compared to 2014 is the result of the growth in China auto market because in 2015 the growth in the rest of the world was negative (fig. 5.1). The recent year-over-year sales growth of BEV is even brisker in China; in 2015 China accounts for 45% of global BEV sales compared to 26% and 13% in 2014 and 2013 respectively (fig. 5.2).

Table 5.1
How much China accounts for global conventional passenger car sale

year	Sales in China (in million)	Total sales in the world (in million)	China accounts for (%)
2015	21.20	66.32	31.96
2014	19.37	65.08	29.76
2013	17.52	62.69	27.94
2012	15.25	60.42	25.23
2011	13.69	56.85	24.08
2010	12.55	54.40	23.06
2009	10.25	49.41	20.74
2008	6.23	49.29	12.63
2007	5.00	49.36	10.12
2006	4.68	47.30	9.89
2005	4.16	45.44	9.15

Source: China Statistics Press (2017), Oica.net

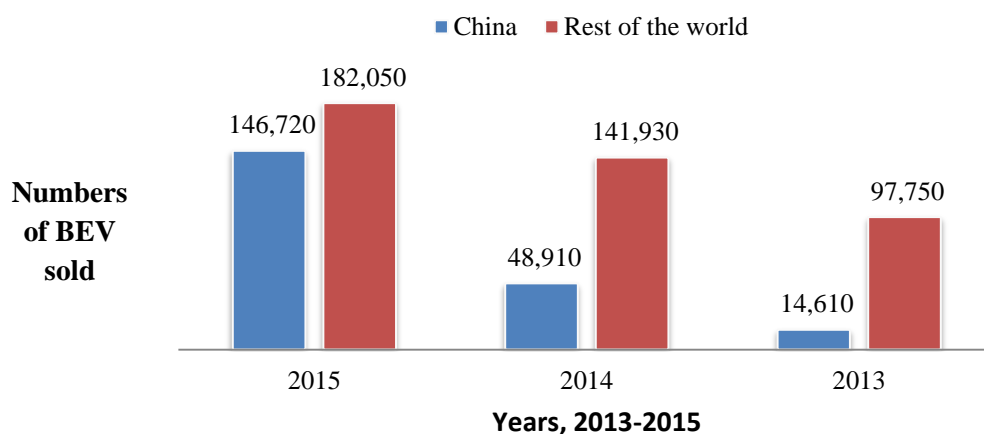


Figure 5.2: BEV sales in China and rest of the world; Source: IEA (2016)

5.2 The prospect of automotive market in China

Dargay et al., (2007) estimated that in China car ownership per 1000 population will be 269 units with one of the highest annual ownership growth rate of 10.6% and total car population will be 390 million in 2030. This projected number of cars in 2030 for China is 20 times it had in 2002. According to Baker Institute projection, the growth in Chinese auto market will continue in coming years and by 2040 there will be estimated 750 million vehicle (this projection includes cars, vans, buses and trucks). Dargay et al., (2007) mentioned that the growth in Chinese auto market is due to two reasons: one, its high rate of income growth; second, its per-capita income is associated with car ownership, but it is expected that in this period its car ownership rate will be growing more than twice as fast as income which means that car ownership will grow twice as rapidly as per-capita income. In the same research, Dargay et al., (2007) estimates that the car ownership saturation per 1000 population is 807 units for China. Thus, it can conclude that the gap between current point to the saturation point is much higher for China; currently it is estimated that the per 1000 population the ownership rate is around 125 unit (fig, 5.6).

Wang et al., (2012) forecasted that China's vehicle population will increase by 13 to 17 percent per year reaching as many as 419 million vehicles in 2022 and mentioned that If the Chinese economy continues to boom, and if China does not aggressively restrict its car ownership, then this forecast scenario of higher vehicle growth will likely to happen in future (Wang et al., 2012). China's car population in 2015 was 172 million (Statista, 2017). Forecast from Dargay et al., (2007) and Wang et al., (2012) suggests that Chinese auto market yet to grow a log way and therefore, planned penetration of electric vehicles with proper EV policy in Chinese market will have strong impact in energy demand and environment. Fig. 2.6 also illustrates the possible rapid growth of vehicle fleets in non –OECD emerging economies, especially China and India.

On the other side, the scenario is different for Norway; Dargay et al., (2007) estimated that the car ownership saturation per 1000 population is 852 units and current ownership per 1000 population is around 505 units.

Gissler et al., (2016) studied on the EV market attractiveness and categories the market into four types: Best-in-Class, High potentials, Hesitators and Pensioners. Gissler et al., (2016) placed China and USA into 'Best-in-Class' category and Norway in 'High Potential' category. Best-in-Class market is kind of market that provides both great market size and

high market growth perspective while High Potential market provides high growth perspective but currently has a lower market size. Best-in-Class markets are more attractive for OEMs.

5.3 Electric vehicle market differences between Norway and China

The market of electric vehicles in Norway and China differs both in magnitude and development aspects. It is noticeable that China’s electric vehicle market is massively larger than Norway in magnitude while Norwegian EV market’s consistent development sets example for not only China but also for any other countries in the world. Fig. 5.3 displays that the EV market share in China remains same for 2012 and 2013 while development in Norwegian EV market continues gradually through years taking a briskly rise from 5.80% to 13.70% (2.36 times) in 2014. The brisk rise of EV market share in Norway from 2013 is certainly the result of aggregate impacts of all implemented policy measures (by 2013, Norway have implemented purchase incentives, use incentives and allowed waivers on access restrictions), availability of improved, advanced EV models and large investing for charging stations (tab. 2.4). Year-over-year EV market share growth for China starts to increase rapidly from 2014 resulting from additional incentives and improved policy measures (reduced license plate auction price in Shanghai, exempted traffic restriction in Beijing) in pilot cities along with national incentives and large investment for charging infrastructures (number of charging infrastructure increased almost 2 times in 2015 compared to 2014).

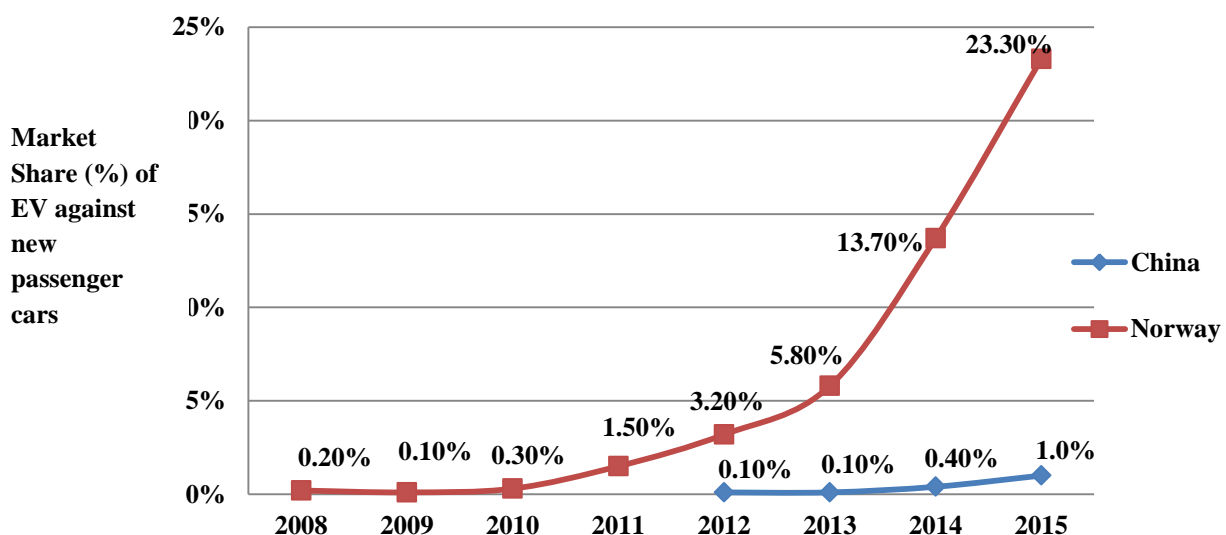


Figure 5.3: Market share (%) development of EVs (BEVs and PHEVs) in Norway and China, 2008-2015; Source: IEA (2016)

In both Norway and China, BEV dominates the market; in 2015, BEVs account for 70.7% and 78% of new registered EVs in China and Norway respectively (IEA, 2016). Fig. 5.4 illustrates the evolution of BEV shares in both countries. The obvious reason behind the remarkable BEV evolution in Norway automotive market is their nationwide BEV-focused policy measures. BEV buyers are given privileged by every policy measures implemented in Norway, on the other side, PHEV buyers are entitled to benefit less from purchase incentives, use incentives and are not allowed to enjoy the bus lane access. In China, different levels of incentives are provided depending on types of EVs and drive ranges but the differences between incentive levels are not significant and moreover, the BEVs are not entitled to be privileged by any other incentives, e.g. use incentives.

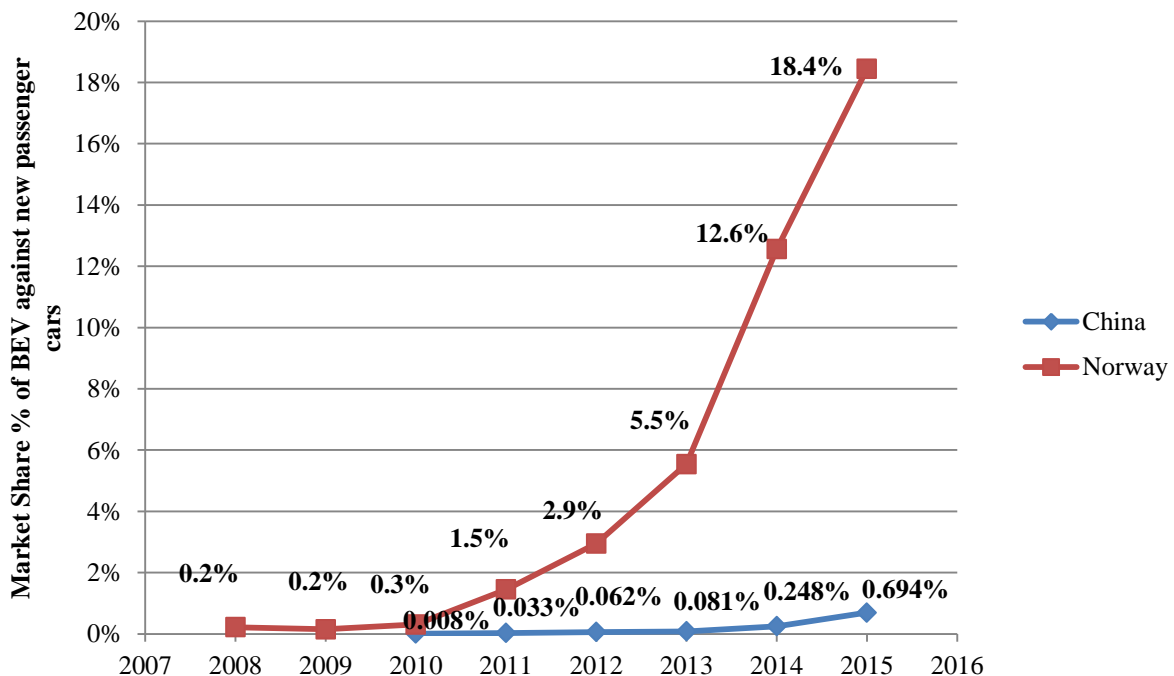


Figure 5.4: Evolution of BEV shares against total passenger cars in Norway and China, 2008-2015; *Source: IEA (2016) and globaleconomy.com.*

As per IEA (2016), Norway and Netherlands are the only countries with EV stock shares above 1% and Norway is the only market where they have above 1% share of BEVs against passenger cars stocks (fig 5.5).

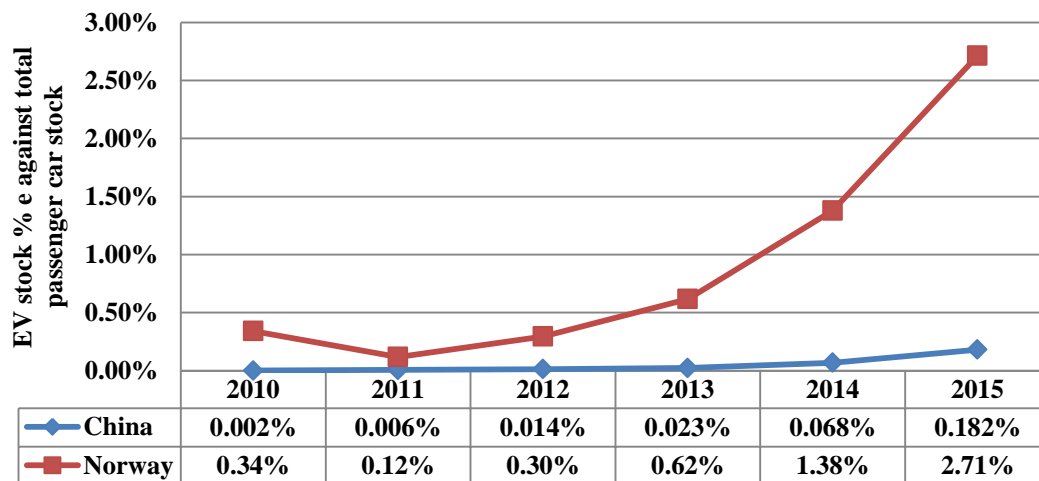
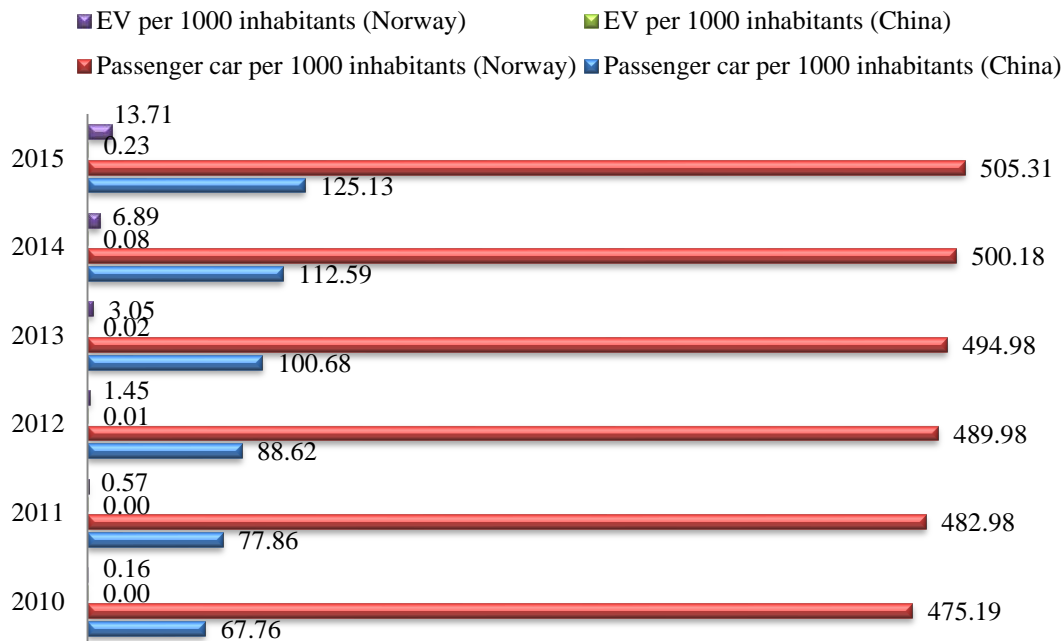


Figure 5.5: EV (BEVs and PHEVs) stock percentage against total passenger car stock, 2010-2015; Source: IEA (2016), statista.com, ssb.no

Fig. 5.6 illustrates the car ownership differences between Norway and China. Electric vehicle ownership per 1000 inhabitants in Norway starts growing from 2013 which is consistent with EV market share development displayed in fig. 5.3. Still China has been struggling to have at least 1 EV owner per 1000 inhabitants even though EV sales have been increasing rapidly for last 3 years. Moreover, China's EV stocks percentage against total passenger cars is yet far below than 1%; only 0.182% (fig 5.5). On the other hand, In Norway EV ownership rate is almost 14 (13.71) per 1000 inhabitants. The car ownership per 1000 inhabitants in China is increasing (year-over-year) by average of 13% annually over last few years (2011-2015) but yet saturation point for car ownership per 1000 inhabitants is in distant considering the expected car ownership saturation point (807) forecasted by Dargay et al., (2007). The car ownership per 1000 inhabitants in Norway is also increasing gradually but compared to China the growth is slow as in last 6 years China's number gets doubled, from 67.76 to 125.13.



Figures 5.6: Passenger cars and EVs per 1000 inhabitants in Norway and China, 2010-2015; Source: *ssb.no, IEA (2016), China Statistics Press (2017), statista.com*

5.4 Impact of individual policy measures on EV market share

The impact of policy measures from Eq. 4 is derived from selected previous studies and journal publications. The policy measurers are purchase incentive, P, use incentives, U, waiver on access restrictions, W, charging infrastructures, I, communication process, C, Availability of different brands, A and their parameters or coefficients are β_1 , β_2 , β_3 , β_4 , β_5 and β_6 respectively.

Bakker and Trip (2013) make an assessment of policy options to support the adoption of electric vehicles in the urban environment. The assessment ranked different measures on their effectiveness, efficiency and feasibility. Charging infrastructures, providing information to businesses and customers, exemption from toll fees and allowing EVs to drive on bus lanes are assessed as important measurers along with few other policy measures to support adoption of electric vehicles. The scores of these policy measures are given in Table 5.2. The score of each policy measure is on scale of one to five in terms of the measure's effectiveness, efficiency and political feasibility. In the assessment a policy measure's effectiveness is defined as its impact on the uptake of EVs, efficiency refers to the costs that are involved in comparison to the measure's impact and feasibility is defined as the

likelihood of a policy measure that can indeed be implemented given its financial, social, and political costs. (Bakker & Trip, 2013). The full ranking is given in Appendices 1

Table 5.2
Average scores for the selective policy measures on their effectiveness, efficiency, and their feasibility, Source: Bakker and Trip (2013)

Policy measures	EVMS model variables	Average Score	Effectiveness	Efficiency	Feasibility
Charging Infrastructure	I	4.17	4.33	4.17	4
Providing Information to businesses and customers/ Public awareness	C	3.83	3.83	3.83	3.83
Exemption from toll fees	U	3.33	4.00	3.40	2.60
Allowing to drive in bus lanes	W	3.20	3.80	3.60	2.20

Sierzchula et al., (2014) analyzed the influence of financial incentives and other socio-economic factors on electric vehicle adoption. Based on 2012 data of several countries, Sierzchula et al., (2014) concluded the correlation of several factors (e.g. purchase incentives, urban density, education, environmental regulations, national income, availability of models) with EV market shares. In the table 5.3, the relevant policy measures to this research are only mentioned. The correlation of charging infrastructure and purchase incentive is statistically significant at 0.01 level (2 tailed) and availability of model is statistically significant at 0.05 level (2 tailed).

Table 5.3
Correlation of individual incentives with EV market share (%)

Policy Measure	EVMS model variables	Correlation with EV market share
Charging Infrastructure	I	0.697
Number of model availability	A	0.375
Purchase Incentives	P	0.498

Source: Sierzchula et al., (2014),

Note: Market share means national market share of electric vehicle/BEVs as a percentage of all car sales and financial incentives include incentives that countries provide for the purchase of an electric vehicle.

Fearnley et al., (2015) used the tobit model to measure the relative importance of the local BEV incentives and individual effect of those local incentives on EV market share. The tobit model combines a probit model ($\text{Prob}(y>0)$) and a truncated regression ($E(y>0)$) and the interpretation of tobit coefficients are much in the same way as OLS regression coefficients. In the analysis, Fearnley et al., (2015) looked into four particular zones in Oslo-Kongsberg region but the contribution of individual incentives to BEV market share (%) mentioned in table 5.4 is the mean of all zones representing the contribution of those individual incentives in Norway as whole.

Table 5.4
Contribution of individual incentives to BEV market share (%), (in Norway)

Policy measures	EVMS model variables	Contribution to BEV market share (%)	
Free Parking	U	0.01	β_2
Road Charges		0.18	
Ferry Fee		0.03	
Bus Lane	W	0.05	β_3

Source: Fearnley et al., (2015)

Free parking, exemption from road tolls, ferry fees and access to bus lanes are widely used in Norway while very few other countries implemented these policy measures as widely as Norway (Appendices 1). Therefore, in this research for further analysis and for simplicity, the estimated contribution of these individual policy measures to BEV market share would be considered as standard for all other countries, which means it would be considered that other countries will have equivalent EV market share changes by introducing these EV policy measures.

In order to quantify the impact, Sierzchula et al., (2014) regressed the log of EV market share on several financial incentives and other socio-economic factors. The result shows that the coefficient (beta value) for financial incentives and charging infrastructure were positive and statistically significant with P-value of 0.039 and 0.004 respectively and charging infrastructure has greater beta value than beta of financial incentives. From W. Sierzchula et al., (2014) research analysis it can be concluded that holding all other factors constant, each 1000 USD increase in purchase incentives, P, would cause a country's EV market share to increase by 0.06% (β_1) while each additional charging infrastructure, I, per 100,000 residents would increase a country's EV market share by 0.12% (β_4). (Sierzchula et al., 2014)

Jin and Slowik (2017) assert the importance of public awareness or communication process for EV adoption. Jin and Slowik (2017) didn't quantify the impact of communication process (β_5) on EV market share rather to emphasize the importance, enlisted few major research results that worked on the public awareness or communication process for EV adoption. Selected previous studies and journal publications that demonstrate the importance of public awareness or communication process are shown in table 5.4. From the table 5.4 it is certain that the lack of awareness and knowledge are barrier for mass EV adoption. The surveys and findings support the significant correlation between buyers' positive attitude towards EV purchase and their awareness, knowledge about EV. (Jin and Slowik, 2017)

Table 5.5
Selective previous studies evaluating the importance of consumer awareness *Source: (Jin and Slowik, 2017)*

Author	Years	Title	Core Analysis result
Bunce et al.	2014	Charge up then charge out? Drivers' perceptions and experiences of electric vehicles in the U.K.	After three month driving-trial, 74% of drivers expressed willingness for EVs compared to 51% before the trial.
Cahill et al.	2014	New car dealers and retail innovation in California's plug-in electric vehicle market	Consumer experience with EVs can be greatly improved by introducing new approaches for educating and scaling dealer competence regarding electric vehicles.
Consumer Federation of America, CFA	2015	Knowledge affects consumer interest in EVs, new EVs guide to address info gap	The research analysis discovered that there is significant correlation between EV knowledge and positive attitude which leads to purchasing willingness. Thus, the more buyers or consumer are knowledgeable the more purchase desire; there is significant correlation between them.

Author	Years	Title	Core Analysis result
National Research Council, U.S.A	2015	Overcoming barriers to the deployment of plug-in electric vehicles	The major barrier to EV's widespread adoption is lack of awareness and knowledge
Egbue & Long	2012	Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions	Consumer attitudes and uncertainty regarding EV technology and sustainability of fuel sources may be results from lack of understanding and familiarity; this is considered as a barrier to widespread adoption

Note: it is continuation of table 5.5

The impact of availability of different EV brands (β_6) on EV market share is not quantified by any previous studies. But previous studies support that there is brand image, brand perception and brand loyalty are intensely connected with car buyers buying decision. Morris (2013) finds out that in current digital era the purchase path for auto shoppers is changing over time but the influential brand moments are constant through the cycle that consists pre-market, in-market and post-market phases. Morris (2013) mentions that 63 percent of new car buyers begin their search with specific brand in mind. Smouse (2015) shows an analysis of car sales in 2015 conducted by IHS automotive, which mentions that yet the car buyers staying loyal to car brands. The study shows that almost 52.8% car buyers from United States replaced their old cars with a new car of the same brand according to sale data of first quarter of 2015.

5.5 Parameter for fuel consumption and crude oil demand

Unger (2015) analyzed the impact of total vehicle-in-use on global fuel consumption and the impact of global fuel consumption on global crude oil demand by conducting regression analysis. Unger (2015) results suggest that as impact of total vehicles-in-use for each year, the average change in the mean of global fuel demand per day is about 0.007833 barrels per day (κ) or 1.25 liters per day. This regression was conducted based on historic data 2007-2014.

Unger (2015) analyzed the impact of global fuel consumption on global crude oil demand based on historic data 2007-2014. As per historic impact, for each change of 1 million barrel

per day of fuel consumption, the average change in the man of global crude oil demand is about 3.12 million barrel per day (ρ). This result is recommended as a good proxy since petrol (gasoline) falls in the category of light distillates which means that roughly 30 percent petrol can be produced out of one barrel crude oil. Unger (2015) mentioned that the contribution of fuel or gasoline demand to crude oil demand is partial. Therefore, besides fuel demand other economic factors have contribution in crude oil demand. The other economic factors' impact on crude oil demand doesn't fall in this research scope, thus for the analysis purpose it has considered that crude oil demand is impacted by the fuel (gasoline) demand only. Since the regression analysis in Unger (2015) was conducted based on global fuel consumption and global crude oil demand data, it can be considered as standard measurement for any other countries. For this research analysis purpose, results from Unger (2015) will be taking into account to measure the crude oil demand change both for China and global scenarios.

Chapter 6: Analysis and Discussion

“Men are generally incredulous, never really trusting new things unless they have tested them by experience” Niccolo Machiavelli (Rogers, 1983, p. 271)

This chapter starts with explanation of how the previous studies and theoretical framework support the circumstance that China needs to invest more and upgrade their current EV policy measures to some extent. Afterwards, EV market share (EVMS) model is used to estimate possible market share changes if China adopts similar Norwegian EV policy measures. In later section, the consequences of the crude oil demand in China due to EV adoption based on different scenario are analyzed which is followed by the brief analysis of predicting the next oil crisis that may happen due to mass EV adoption.

6.1 Why does China need more incentives?

As per innovation adoption curve model described in Rogers (1983) China still remains in innovator region considering China's EV market share in 2015 is 1%, which lies within the first 2.5% area from the left of the innovation adopter distribution curve. Being at the beginning of innovator region (fig. 6.1) implies that still China needs to invest more to attract new EV buyers as well as in order to move to the early adopters or early majority region or even further; this can be explained from the fig. 3.4, where it is graphed that increasing sales decreases the willingness of innovators, early adopters to pay for an innovative vehicle technology and as a result, it increases the required subsidies to insure the sale of additional novel vehicle technology. China's position in the innovation adoption curve from the 'diffusion of innovation' theory of Rogers (1983) is shown in fig. 6.1. Possible further incentives can be greater purchase subsidies and/ or EV use incentives and/or incentives in supporting policies. If purchase incentives are considered then in China there are still possibilities to increase the incentives to increase the sale of EVs, especially BEVs or pure electrics, e.g. greater incentives upon EV purchase and/or VAT exemption.

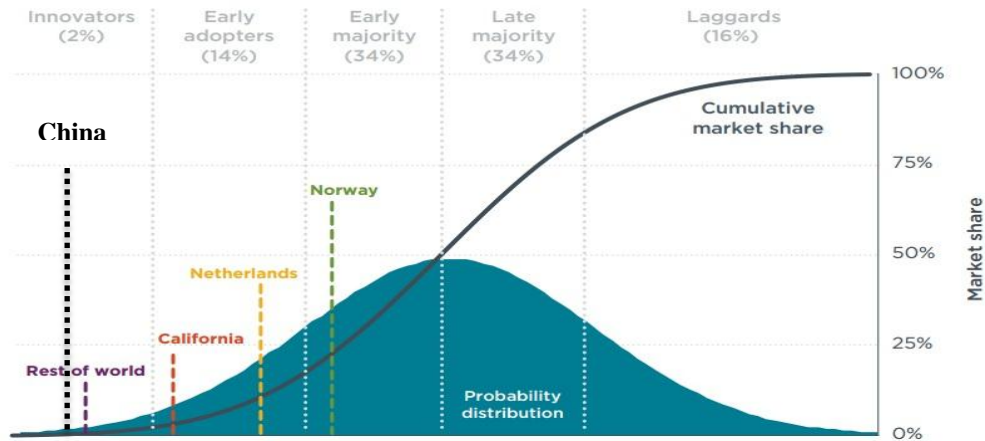


Figure 6.1: Technology adoption curve including select electric vehicle markets; Source: (Slowik & Lutsey, 2016)

Moreover, as per the theory of demand for transport from Button (2010), price and price of alternative transports influences the demand of any specific transport. Therefore, the price of EVs and the price of other passenger cars like, ICE vehicles both influence the demand of EVs in the market. Price of EVs can be made competitive against the price of ICE Vehicles in two effective ways, EVs price can be reduced expansively and/or increase the price of ICE vehicles. According to the theory by Button (2010), if the price of conventional or ICE transport increases making the electric vehicle competitive or comparatively less expensive, or if the price of electric vehicle decreases making the conventional transportation comparatively expensive, either of them pushes the demand curve of electric vehicle upward. Fig. 6.2 shows that the upward shift of demand curve from D_1 to D_2 at any price due to the price changes of alternative transportation. The price of the electric vehicles can be reduced to make it competitive or less expensive than ICE vehicles by lowering the purchase cost and implementing the incentives. It is necessary to mentioned again that if EV price keeps higher than ICE vehicles then it may result otherwise, which is that the demand curve of EV can shift downward (D_2) and fig 2.7 graphed these situations for China. Fig 2.7 already shows that even after the national subsidies the price of ICE vehicles is lower for top sold car models. The situation is different only for the pilot cities where in addition of national subsidies, local subsidies are also applied (fig. 2.3). Therefore, it can be argued that still China needs to invest largely to privilege the EV buyers with higher purchase incentives.

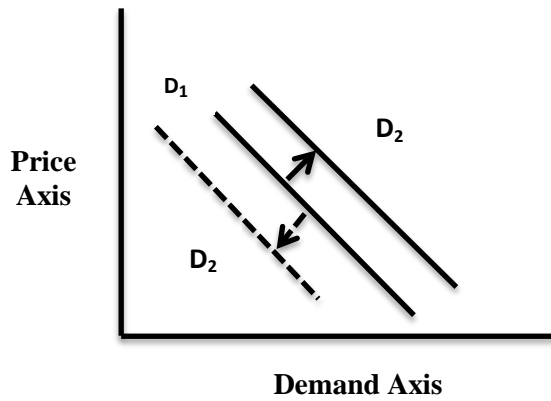


Figure 6.2: Effect of alternative cars price on electric vehicle's demand shift

In fig. 6.3 illustrates that how utilizing different EV incentives can reduce the price of EVs in China. Among mentioned incentives, China already has the purchase rebate incentive national-wide, but they can consider the VAT exemption and lower the base price of EVs further. As second thought, China can consider to increase their rebate amount as well.

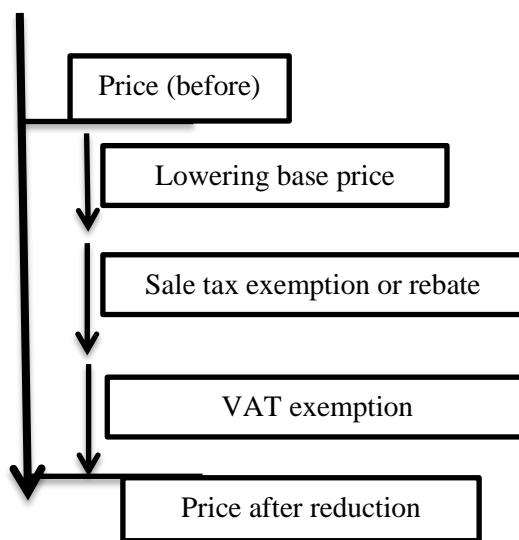


Figure 6.3: Possible way to make the EV purchase price more competitive

In China, the policy of exemption from road toll fees is implemented in certain geographical areas and doesn't have the access to bus lane policy. So China can consider these policy measures to implement nationwide to accelerate the sale of EVs in upcoming years. Fig. 6.4 displays using generalized cost notion from Mathisen (2008), how the policy measures of exemption from toll fees and access to bus lanes (considering time value) can impact in lowering EV generalized cost. According to theory, lower generalized cost can increase the

demand of electric vehicles. Policy measures of charging infrastructures and providing information to businesses, customers (public awareness) will be discussed in later section.

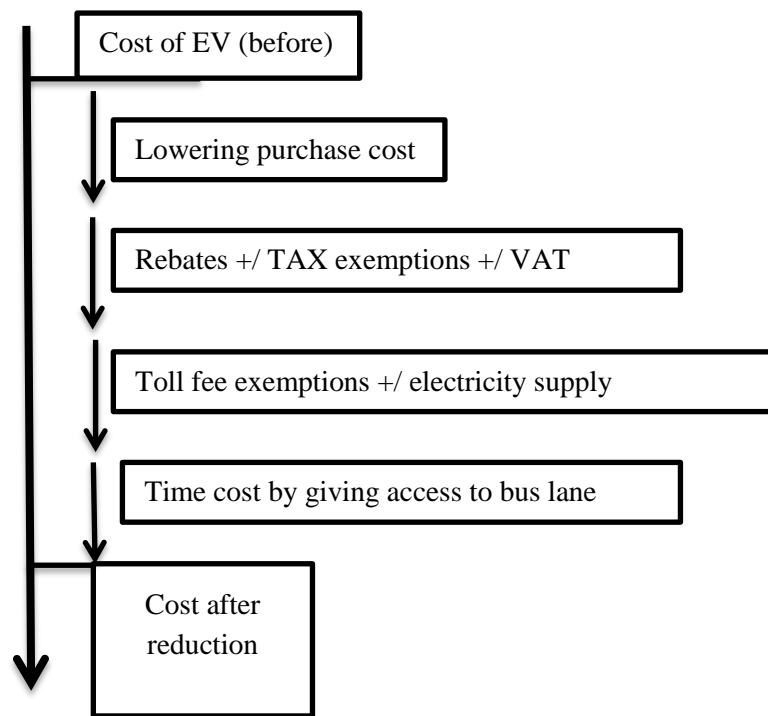


Figure 6.4: How the generalized cost of electric transport can be lowered

6.2 Does China need to invest more on supporting EV policy measures?

6.2.1 Charging Infrastructures or EVSE

The importance of building more EVSE or charging infrastructure in China is illustrated in earlier section 2.5.4 where lack of charging infrastructure in China is demonstrated as one of the major obstacles for EV adoption. Moreover, table 5.2 ranks charging infrastructure top of the table (total score 4.17/5) judging its effectiveness and efficiency for EV adoption. The coefficient value (each additional charging infrastructure per 100,000 residents would increase a country's EV market share by 0.12%) of charging infrastructures itself demonstrates its importance.

In theoretical framework, it is mentioned that in order to increase the sale of EV (innovative product) after the early innovators phase the social cost (subsidies or investments) needs to be increased. Thus, more investment is required in building charging infrastructures. China has already considered the problem and has started investing to reach a certain target by 2020. On the other hand, the increase of EV sales will require building more charging infrastructures to supply charging facilities for the increased EVs. Therefore, it is kind of

continuous process but it is expected that the cost of building infrastructure will get less gradually after a certain level.

In order to increase the charging facility China can consider diversifying the charging ways as well to adopt EV market. For example:

- Battery switch service can be considered. Such service can be considered to bring into different petroleum stations or in places where building electric charging infrastructure may be difficult or will require more additional infrastructure building.
- Charging piles can be constructed in populated areas, e.g. vehicle parking lots. Shanghai is now working on such project to build charging piles in city parks and vehicle parking places.

6.2.2 Communication process

According to innovation decision-process stages, before making buying decision consumers need to have knowledge about the innovation to build positive attitude towards it. As already discussed earlier, car buyers in China is not properly aware of many practical and updated information about the electric vehicle incentives and furthermore, few cities still solely rely on the EV manufacturer to spread information or knowledge. So, it is certain that there is communication distance in China. Communication or information flow about all aspects of EVs to the car buyers can be done through several communication channels. Rogers with Shoemakers (1971) made a comprehensive analysis and concluded that mass media channels have relatively greater importance at the knowledge function for both developed and developing countries (Rogers, 1983). It has been already discussed that electric vehicle market in China is currently at innovator stage and is approaching towards the early adopter stage. Rogers (1983) also gave answer about the channels that can play key role in early adopter stage to keep flow the innovation related information among the individuals in social system to complete the innovation-decision process. Mass media channels are relatively more important to spread information and Rogers (1983) recommends that mass media channels are relatively more important than interpersonal channels at the knowledge stage and for earlier adopters. Mass media is cosmopolite type channel based on the origin of information and Rogers (1983) also recommended that cosmopolite channels are relatively more important than local channels for earlier adopters and one of the reasons is mass media can spread information rapidly and widely and in the innovation-decision process earlier adopter have shorter innovation decision period than later adopters e.g., early majority, late majority.

Therefore, the studies suggest that it high time for China to spread knowledge about electric vehicles among the individuals of social system via mass media mostly. Further, alike Norway, China can encourage local agencies to spread the practical knowledge about electric vehicles.

6.2.3 Availability of different EV brands

Earlier discussion (section 2.5.4) demonstrates that Chinese EV consumers expressed that they don't have enough EV brand options. Furthermore, they have preferences to foreign or international brands for buying cars. But Chinese EV market is limited to the local brands. Brand loyalty in buying caring is nothing new. Studies (in section 5.4) from Morris (2013) also support the concept that brand image, brand positioning works effectively when new car buyer make their car buying decisions. Thus, with the support of previous studies it can conclude that China EV market needs to allow more different EV brand, especially the foreign or international EV brands.

6.3 The possible EV market share changes by adopting Norway's EV policy

The possible market share change by adopting similar Norwegian EV policy is calculated using the electric vehicle market share (EVMS) model (Eq. 4). Below the full calculation process is described for each variable.

D) Charging infrastructures

Already mentioned in previous chapter that in 2015 publicly accessible charging infrastructures (EVSE) per million inhabitants in Norway was 1372 while for China the number was only 42 (IEA, 2016).

According to the studies from Seirzechila et al., (2014), each additional charging infrastructure per 100,000 residents would increase a country's EV market share by 0.12%. Therefore, the value of parameter, β_4 , of charging infrastructure, I, refers that if China has as many as publicly accessible charging infrastructures per 100,000 inhabitants Norway does, holding all other factor constant, alone charging infrastructures can increase the EV market share by 16%. The calculation break-down is shown in table 6.1

Table 6.1
Calculation break-down of the impact of charging infrastructures, I, in China EV market share

	Norway	China
Publicly accessible charging infrastructures per million inhabitants	1372	42
Difference between the number of charging infrastructures per million inhabitants	1330	
Each additional charging infrastructure per 100,000 residents would increase a country's EV market share by 0.12%.		
Required publicly accessible charging infrastructures per 100,000 inhabitants to have as much as Norway does		(1330/10) =133
Therefore, Market share will increase by		(133 x 0.12%) = 16%

Thus, based on 2015 EV market share in China (1%), if China had publicly accessible 137.2 charging infrastructures per 100,000 inhabitants, then in 2015 holding all other factors constant, China would have EV market share of 17% (1%+16%); this is considerably very high impact on EV market share.

II) Purchase Incentives

As per IEA (2016), Norway provides \$20,000 on average only as purchase incentives for BEVs while China provides \$10,000 on average for BEVs. For PHEVs purchase, Norway provides purchase incentives slightly more than \$10,000 on average and China provides slightly more than \$5000 on average. For simplicity, in this research analysis, the purchase incentive for PHEVs is assumed as \$11,000 in Norway and for China the purchase incentive is assumed as \$6000.

According to the studies from Seirzechila et al., (2014), each \$1000 increase in purchase incentives would cause a country's EV market share to increase by 0.06%. Therefore, the value of the parameter, β_1 , of purchase incentives, P, refers that if China has equivalent purchase incentives for both BEVs and PHEVs as Norway, holding all other factors constant China can increase EV (both BEV and PHEV) market share by 0.9%. The calculation break-down is shown in table 6.2.

Table 6.2
Calculation break-down of the Impact of purchase incentives, P, in China EV market share

	Norway	China
Purchase Incentive for EV (BEV and PHEV), on average	(20,000+11,000) \$31,000	(10,000+6000) \$16,000
Difference between the amount of purchase incentives	\$15,000	
Each \$1000 increase in financial incentives would cause a country's EV market share to increase by 0.06%		
Therefore, if purchase incentive is as much as Norway, the market share will increase by		(15 x .06%) 0.9%

Thus, based on 2015 EV market share in China (1%), if China had as much as purchase incentives for EV Norway does, then in 2015, holding all other factors constant, China would have EV market share of 1.9%(1%+0.9%).

To introduce the new policy measures or to invest more for policy measure will certainly increase the social cost but it is also possible to cover or reimburse the investment by going stricter for conventional vehicles (ICE vehicles) and for GHG emission and by increasing social benefits e.g. 1) By increasing purchase incentives for BEVs and simultaneously lowering the incentives for PHEVs will motivate consumers to buy more BEVs which will increase the social benefits, 2) Imposing higher tax, VAT and other fees (parking fees, road-tolls) on ICE vehicle has two outcome; demotivating consumers to buy ICE vehicles and to earn from consumers who still consider to buy them.

III) With all the policy measures together

As per electric vehicle market share (EVMS) model if China follows all the necessary EV policy measures then the overall EV market share increase will be even higher. The EVMS model includes all the effective EV policy measures Norway does and in addition it considers availability of different EV brands, A, as another factor to increase country's EV market share. Thus, if China introduces as much as purchase incentives, P, Norway does, builds as many as charging infrastructures, I, as Norway does, and introduces same use incentives, U, wavier access, W, for EVs as Norway does then China's EV market share will increase largely. The calculation break-down is shown in table 6.3.

Table: 6.3

The contribution of all necessary EV policy measures to the market share, In China; combing the table 5.4, 6.1, 6.2

Policy measures	β	Contribution to EV market share (%)		
		With same number of charging infrastructure	With half of number of charging infrastructure	With 1/4 of number of charging infrastructure*
Purchase Incentives	β_1	0.9	0.9	0.9
Free Parking	β_2	0.01	0.01	0.01
Ferry Fee		0.03	0.03	0.03
Road Charges		0.18	0.18	0.18
Bus Lane	β_3	0.05	0.05	0.05
Charging infrastructures	β_4	16	8	4
Total market share changes		17.17%	9.17%	5.17%

***Note:** China has target to deploy 0.5 million public chargers for cars by 2020 which is close to the estimated numbers of publicly accessible EVSE stock (470,328) if China builds at least one fourth (1/4) of publicly accessible EVSE stock Norway has in per million of inhabitants.

Therefore, it can conclude that if China had the similar EV policy measures as Norway in 2015, China would have EV market share of $(1+17.17) = 18.17$ in 2015.

From table 6.3, it is certain that charging infrastructures is the most important factor for China to increase their EV market share even though as per 2015 data China possess 44 % of global publicly accessible fast charging outlet and 29% of global publicly accessible slow charging outlet. It needs to be noted that the impact of charging infrastructure to increase market share is evaluated by each additional charging infrastructure per 100,000 residents or inhabitants and to calculate the number of charging infrastructure per 100,000 inhabitants, total population of the countries and total charging infrastructures of respective countries are considered. Therefore, even having the highest number of charging infrastructure in 2015, China's charging infrastructures per million habitants in very lower comparatively as China's population is approximately 1.3 billion (in 2015). Logically, it's also fact that the larger population requires more charging infrastructures to make it proportionally available for all the population. In table 6.3, the impact of charging infrastructure exposes really high and even if China would have half (1/2) of the charging infrastructure distribution of Norway then it would manage to increase the EV market share by around 8%. According to IEA (2016), China has target to deploy 0.5 million public chargers for cars by 2020 which is close to the

estimated numbers of publicly accessible charging infrastructure (470,328) if China builds at least one fourth (1/4) of publicly accessible charging infrastructures as Norway has in per 100,000 of inhabitants.

It need to be noted the analysis in table 6.3, excludes the impact of communication process (β_5) and availability of different EV brands (β_6) due to unavailability of quantitative data of its contribution to EV market share. Therefore if the contribution of communication process, C, or public awareness and availability of different EV brands, A, could be counted then there would have further impact of combined EV policy measures on the market share of electric vehicles. On the other hand, Ferry fee policy measure might not be required for the geographical positions and in that case its impact can be excluded.

6.4 The consequences for Crude oil demand in China due to EVs

Several steps have been taken to calculate the consequence for crude oil demand due to EVs.

The steps are:

Step 1: Forecasting the number of conventional passenger cars in China from 2017-2035 using Eq. 5. The forecasting was based on data of number of conventional passenger cars in China from 2005-2010 (table 5.1 or appendix 1)

Step 2: Combining table 6.3, and table 6.5 to forecast of EV market share in China by adopting similar Norwegian EV policy measurers from 2017-2022

Step 3: Forecasting the number of EVs in China from 2017-2022 using Eq. 6 where input is the results from fig. 6.5 and fig. 6.6

Step 4: Forecasting the reduction of fuel consumption in China based on new EV sales each year from 2017-2022 using Eq. 7. Value of parameter, K , and results from table 6.6 are used for this forecasting.

Step 5: Forecasting the reduction of crude oil demand in China based on new EV sales each year from 2017-2022 using Eq. 8. Value of parameter, ρ , and results from fig. 6.7 are used for this forecasting.

Step 6: Forecasting the reduction of crude oil demand in China based on EV stocks in China for each year from 2017-2022 using both Eq. 7 and 8, both parameter, K and ρ . The EV stock was calculated based on results from table 6.6.

The calculation of measuring the magnitude of consequences for crude oil demand due to EVs starts with the projection of passenger car sales, V_t , (2017-2030) in China (Fig. 6.5). The

projection has been done using Eq. 5⁸ or random walk model. Using the random walk model the data set of China's passenger car sales from 2005-2015 (table 5.1) is made stationary by using differences on lagged by one period. According to SPSS analysis result, value of the constant, μ , in Eq. 5 is 1704531.1, where μ is the average period-to-period change.

Fig. 6.5 demonstrates the upward trend or growth of passenger car sales in China and if this growth remains then it will result passenger car stock of around 370 million which is close to the forecast (419 million) from Wang et al., (2012). In fig. 6.5, each year increase was estimated 10% (average) but Wang et al., (2012) is expecting that if Chinese economy growth remains consistent with current pace then car population will increase by 13% to 17% each year.

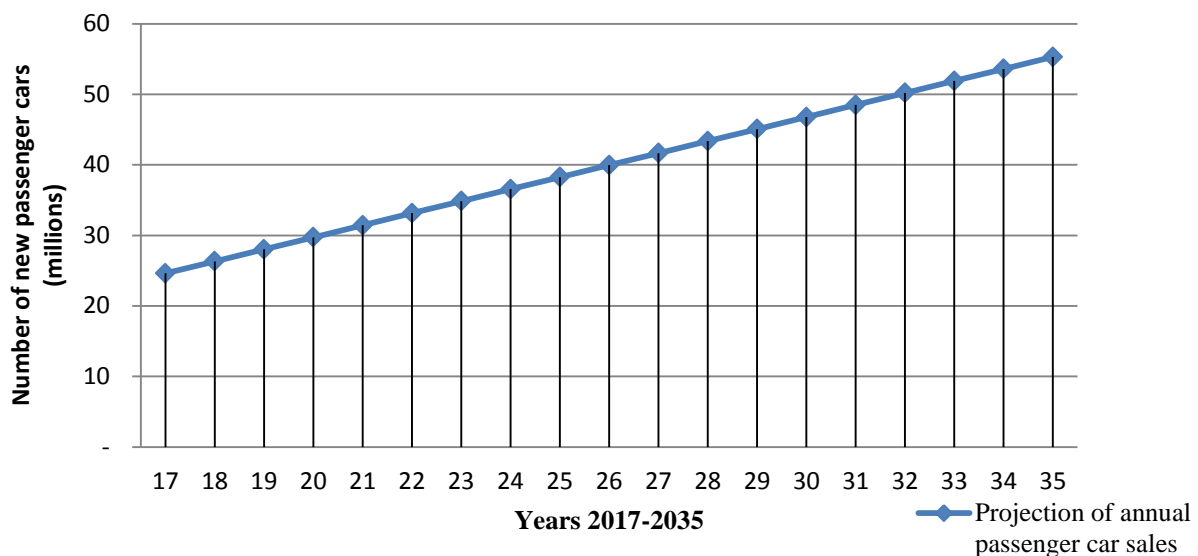


Figure 6.5: Forecast of number of new passenger cars for each year from 2017-2035

Since the development of electric vehicles in China has occurred very recently, there is no sufficient data available to conduct proper forecast using random walk model. Therefore, in order to have better analysis, China EV market share⁹ forecast has been collected from authentic source, Autofacts (2016). Thereafter, results from table 6.3 are combined with Autofacts (2016) forecast (table. 6.5) to calculate China's EV market share in different scenarios which is presented in fig. 6.6.

⁸ Equation 5: $[(V_t) = \mu + V_{t-1}]$

⁹ Market share: National market share of electric vehicles as a percentage of all car sales. (e.g. market share in 2017 represents the market share of electric vehicles as a percentage of all new passenger car sales in 2017)

Table 6.5:

Forecast of China EV market share of all new cars, 2017-2022; Source: (Autofacts, 2016)

	2017	2018	2019	2020	2021	2022
Projected EV market share	2.29	2.71	3.71	3.54	3.588	4.19

Fig. 6.6 illustrates that deploying different targeted number of charging infrastructures along with the adoption of other Norwegian EV policy measures, China can increase EV market share further than forecasted by Autofacts (2016). The possible market share changes by adopting similar Norwegian EV policy is calculated by using Eq. 4¹⁰ in earlier section. Afterwards, the calculated result of possible market share changes is combined with table 6.5 data and presented in fig. 6.6

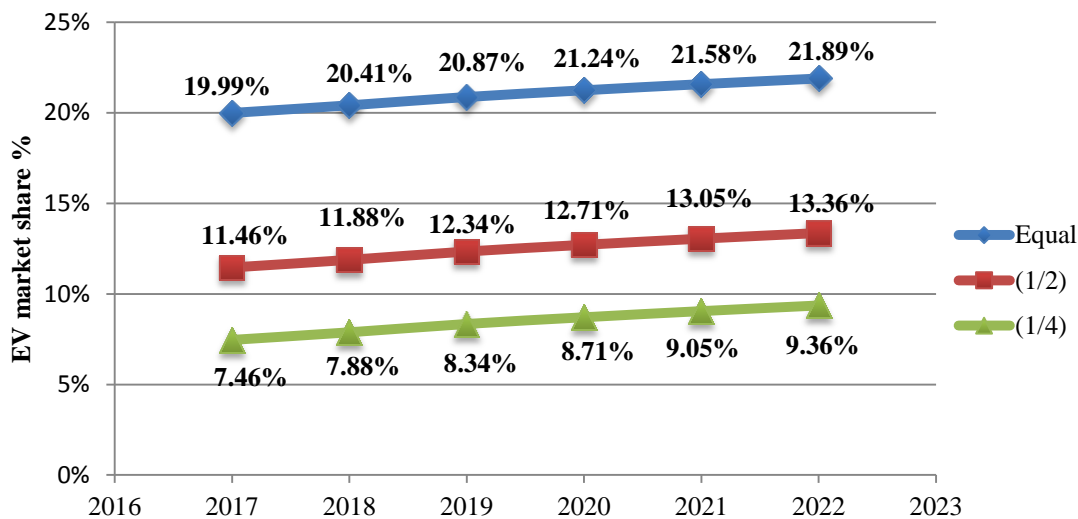


Figure 6.6: Forecast of EV market shares of all new cars by adopting Norwegian EV policy with different charging infrastructure scenarios, China (2017-2022); combining table 6.3 with table 6.5

**Note: the descriptions of market share, Equal, (1/2), (1/4), are given below*

Fig. 6.7 presents the fuel consumption changes in China due to the increase of EV market share over years. To calculate the fuel consumption changes, the value of parameter, K, from Unger (2015) has applied in Eq. 7¹¹. But it is required to calculate the estimated number of EVs using Eq. 6¹² before calculating the estimated impact of the fuel consumption changes (F_t). Table 6.6 shows that China can have high number of electric vehicles if they adopt the

¹⁰ Equation 4: $[EVMS = \alpha + \beta_1 P + \beta_2 U + \beta_3 W + \beta_4 I + \beta_5 C + \beta_6 A + \varepsilon]$

¹¹ Equation 7: $[F_t = E (EV_t) * \kappa]$

¹² Equation 6: $[EV_t = E (V_t) \delta_t]$

Norwegian EV policy measures. Here, it needs to be mentioned that China has a target of have 4.3 million electric vehicle stocks on road by 2020 (IEA, 2016). And by following the forecast by Autofacts (2016) China cannot reach its target by 2020. Rather the results from table 6.6 demonstrate that China can reach its targets by upgrading its EV policy measures similar to Norway EV policy measures. At least building one fourth (1/4) of charging infrastructures of Norway has per 100,000 inhabitants along with enforcing other similar Norwegian EV policy measures (P, U and W) can push China to achieve its EV stock target by 2020.

Table 6.6
Forecast of numbers (in thousand) of new EVs sales for each years based on different scenarios (detail Numbers are in appendix 1)

	2017 (‘000)	2018 (‘000)	2019 (‘000)	2020 (‘000)	2021 (‘000)	2022 (‘000)
Autofacts (2016)	563	713	888	1,052	1,219	1,388
Equal	4,919	5,371	5,847	6,313	6,782	7,253
(1/2)	2,820	3,126	3,457	3,778	4,101	4,426
(1/4)	1,836	2,073	2,336	2,589	2,844	3,101

**Note: the descriptions of Equal, (1/2), (1/4), are given later*

The projection of the reduction of fuel consumption due to electric vehicles is illustrated by four different scenarios (3 scenarios – based on adopting Norwegian EV policy measures with different number of charging infrastructures and one scenario is based on forecasted EV market share by Autofacts (2016)). Electric vehicle can impact the crude oil demand only by fuel consumption changes and from fig. 6.7 it is clear that the fuel consumption and electric vehicle has reverse relationship; the more electric car the more less fuel consumption.

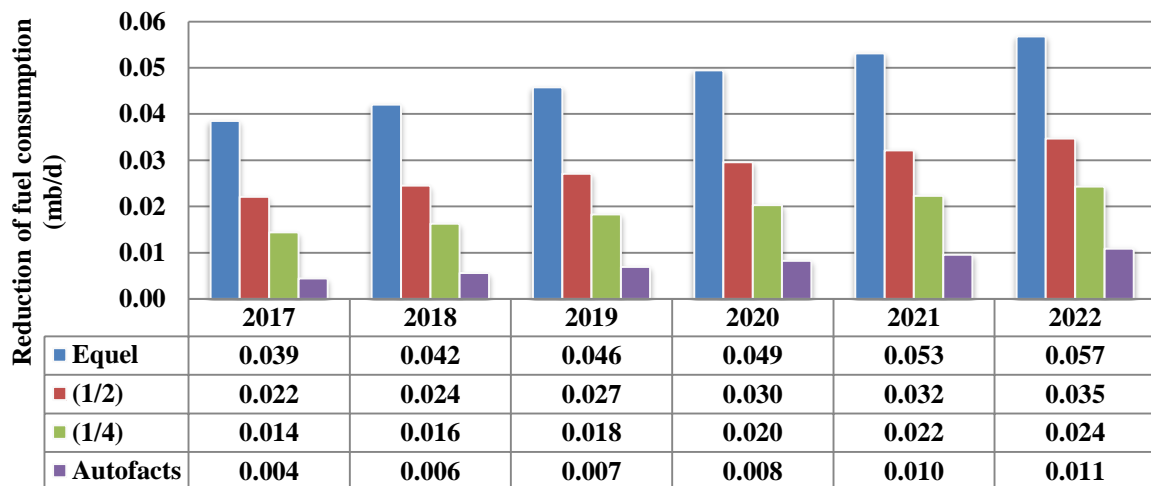


Figure 6.7: Forecast of reduction in fuel consumption based on new EV sales for each year 2017-2022, China; *Note: the descriptions of Equal, (1/2), (1/4), are given later*

Fig 6.8 presents crude oil demand changes in China due to the increase of EV market share over years. To calculate the crude oil demand changes, the value of parameter, ρ , from Unger (2015) has applied in Eq. 8¹³.

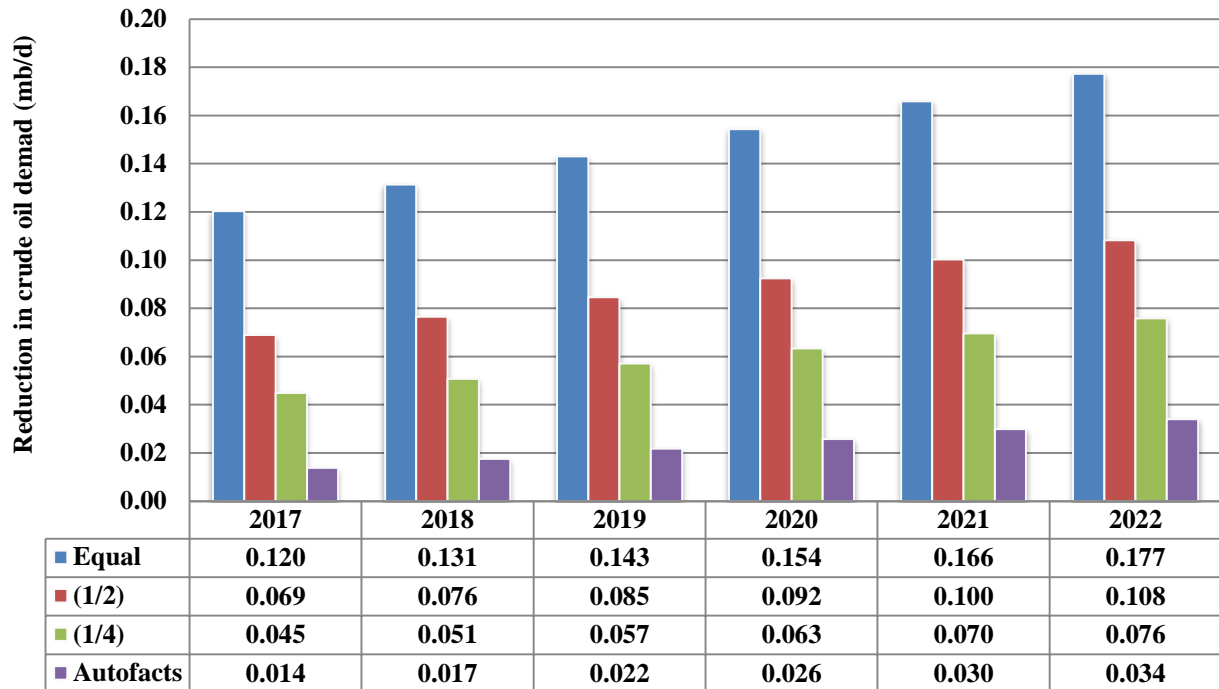


Figure 6.8: Forecast of reduction in crude oil demand based on new EV sales for each year 2017-2022, China

Notes:

Autofacts: Based on projection of EV market share by Autofacts

Equal: Based on scenario where China adopted similar Norwegian EV policy with equal number of charging infrastructure as Norway

(1/2): Based on scenario where China adopted similar Norwegian EV policy with half of number of charging infrastructure as Norway

(1/4): Based on scenario where China adopted similar Norwegian EV policy with one fourth (1/4) of number of charging infrastructure as Norway

The crude oil demand changes as a result of the changes in fuel consumption due the electric vehicles. Fig 6.8 demonstrates that fuel consumption and crude oil demand has positive relationship which means, the less fuel consumption the less crude oil demand; which is apparently the more electric vehicles the less crude oil demand. This chain impact of electric

¹³ Equation 8: $[E (C_t) = E (F_t) * \rho]$

vehicle has already described by fig. 3.5. From fig 6.8, it can conclude that the impact (reduction) on China's crude oil demand is more in scenarios equals, (1/2) and (14) compared to Autofacts, e.g. in 2020 the difference between market shares of scenarios (1/4) and Autofacts is 5.17% and this difference makes crude oil demand to reduce by 1.42 times (0.026 million barrels per day to 0.063 million barrels per day). In 2015, the crude oil demand of China was 11.97 million barrels per day and thus if in 2022, China has as many as charging infrastructures, I, per 100,000 inhabitants Norway does along with introducing as much as purchase incentive, P, Norway does, and other important policy measures (U and W) then it can manage to reduce oil demand by 0.177 million barrels per day and that represents 1.48% of 2015's oil demand. Collins et al., (2016) mentions that oil demand growth rate in China has averaged 1.2% annually since 2005 while according to BP (2016) data, in 2016 China's oil demand increased by 6.3% and in 2015 the increase was 4.8%. Thus, Fig. 6.8 signifies only electric passenger cars can cut off certain big percentage of annual increase of oil demand but for that China needs to improve their current EV policy measures.

Fig 6.9 accounts for the electric vehicle stocks¹⁴ in China for each year, 2017-2022. According to IEA (2016) data, we have record of electric vehicle stock of China from 2010 and Hao et al., (2011) estimated that the average life span of private passenger vehicles, government and business vehicles are 14.5 and 13.1 years respectively. Therefore, while predicting the electric vehicle stocks up to 2022, is assumed that the electric car sold in 2010 will be still running on road in 2022 (2010+14.5years =2024.5).

It is noticeable that if China manage to accomplish their target of building 5 million charging infrastructures (same as 1/4 scenario) around China along with other similar Norwegian EV policy measures (P, U, W) then China will manage to cut off their oil demand by 0.38 million barrels per day by 2022 which is 3.10% of their oil demand (11.97 million barrels per day) in 2015. If the China EV market just follows the Autofacts forecast, it will manage to reduce 0.15 million barrels per day. In 2022, the difference between the electric vehicle market shares of scenarios (1/4) and Autofacts is 5.17% and hence the difference between reductions in crude oil demand is 1.38 times. Further, by adopting similar Norwegian EV policy with equal number of charging infrastructures China can manage to reduce oil demand by 4.7

¹⁴ Stocks refers to the accumulated of total number of electric vehicles. In 2015 electric vehicle stock of China was 312,290 units.

times of the oil demand reduction possible by Autofact scenario. Thus, the results from fig. 6.9 able to demonstrate the possible significant impact of the Norwegian EV policy measures in future oil demand of China.

The results can be described in other way as well. It is also noticeable that the reduction crude oil demand largely depends on how many charging infrastructures are in the market as it is already found out that charging infrastructures are the most important factor to change the EV market share. Therefore, it can be explained in a way that, the more proper distribution of charging infrastructures among the inhabitants, the more impact in EV market share resulting more reduction in crude oil demand. In Fig. 6.9, the most reduction is calculated if China has as many as charging infrastructures, I, per 100,000 inhabitants Norway does along with introducing as much as purchase incentive, P, Norway does, and other important policy measures such as user incentives (U), allowing EVs for restricted traffic zones and /or bus lane (W).

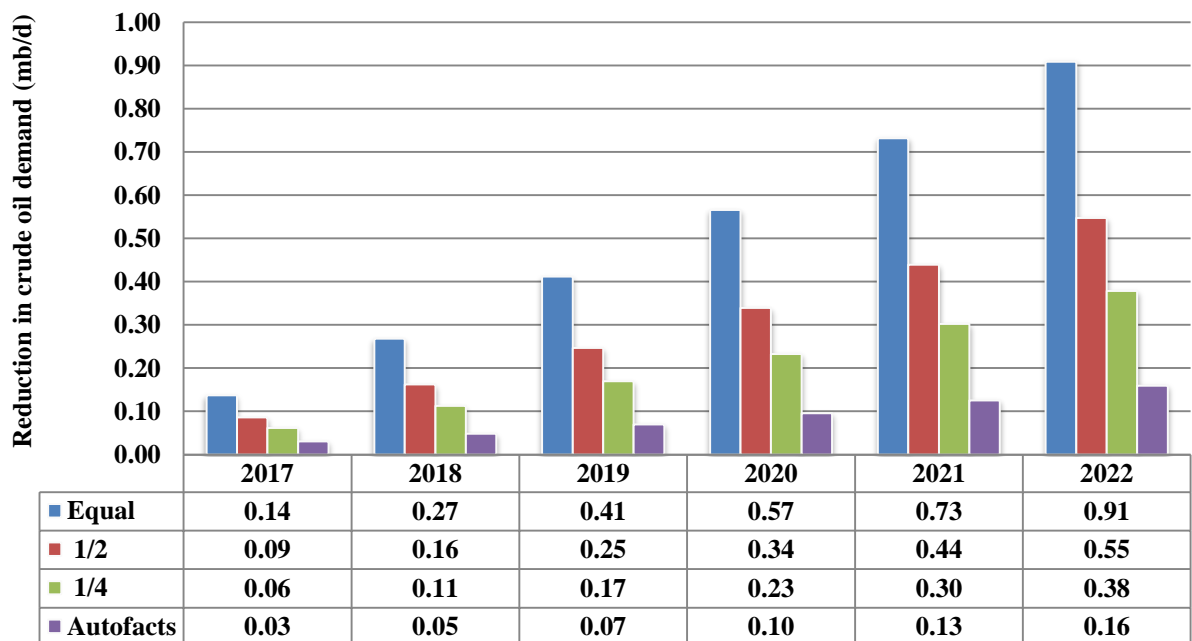


Figure: 6.9: Forecast of reduction in crude oil demand based on EV stocks for each year 2017-2022, China

It is important to note that, in this research, the crude oil demand changes in China is calculated only based on passenger cars numbers. But there are other electric vehicles as well such as buses, trucks, and 2-wheelers. China is ahead of other countries in deploying electric buses on the road. In 2015, global electric bus stock is estimated to be around 17,000 vehicles (around 150,000 of them are battery electric buses) and almost the entire stock is located in China. This statistics proves that China is also turning its public transports into green drives.

Moreover, China is also global leader in deploying electric 2-wheelers. Therefore, it is certain that the impact of all type of electric vehicles on crude oil demand will be more severe. (IEA, 2016)

As already mentioned that the policy measures, communication process, C, and improving the availability of more EV brands, A, are not quantified (due to lack of data) to analysis the EV market share changes but these two policy has very important role to influence the market share and China is really very much lacking with these two policy measures. The necessities of these two policy measures have already discussed in above sections. Therefore, if China adopts also these two important measures then the market share will increase more and as a result the impact on fuel consumption, crude oil demand will be more severe than fig. 6.7, 6.8 and fig. 6.9.

From fig. 6.5 and 6.6 it is vivid that the slops of number of passenger cars and EV market share are upward and it will go upward until it reaches the saturation point and China is still far away to its saturation point. In 2015, china has almost 200% year-over year EV stock growth and for last five years the average year-over year growth for EV stock is around 200% as well. Thus, if China keeps its recent year-over-year growth then within next few years it will manage to have better EV stock percentage against passenger car stock even though China's EV stocks percentage against total passenger cars is yet far below than 1%; only 0.182% (fig 5.5). Table 6.7 illustrates the magnitudes of crude oil demand reduction in 2035 if China's EV stock reaches at different point against passenger car stock. Expecting 10% EV stocks can be considered as aggressive prediction since keeping the current high growth consistently for long will be difficult, but 2% EV stock highly likely within reach by 2035. Assuming to have constant high growth for long may seem aggressive prediction but above analysis shows that if China adopts similar Norwegian EV policy measures it may able to keep its growth rate high for long. The values in table 6.7 is significantly worrying for oil industry as it is demonstrating that alone electric vehicle passenger cars can reduce the oil demand by 1.17 million barrels per day or even 2.33 barrels per day¹⁵

¹⁵ In 2014 the oil crisis happened as a trigger of 2 million barrels per day oil glut (Randall, 2016)

Table 6.7: Possible crude oil demand (mb/d) reduction if EV stock % reaches at difference point against passenger car stocks in 2035, China

Year	2% EV stock	5% EV stock	10% EV stock
2035	0.47 mb/d	1.17 mb/d	2.33 mb/d

The forecast from fig. 6.5 is used to measure the future passenger car stocks in order to calculate the table 6.7. The changes in crude oil demand due to EVs are significant concern for oil industry as the transport sector consumes major portion of oil production. Therefore, the growth of EVs results the less oil demand. If the EV growth keeps growing and if it accompanied with similar Norwegian EV policy measures then the EV stocks in near future will exceed the expectation. The reduced oil demand results in oil surplus which causes fall of oil price. The fall of oil price halts the oil industry and there starts the crisis in oil industry. In 2014, the oil crisis is the result of oil glut of 2 million barrels per day. Table 6.7 signifies if China's EV stock gets 5% of all passenger car stocks then the electric cars in China alone can cause reduction in oil demand by 1.17 million barrels per day which is more than 50% of 2 million barrels per day.

6.5 Global scenarios

If other countries follow Norwegian EV policy measures they will also experience increase in EV market share. Due to lack of complete and authentic information this research analysis isn't able to show the quantified impact of all policy measures from Eq. 4 on other countries' EV market share but the impacts of charging infrastructure on selected countries' EV market are illustrated in table 6.8

Table 6.8 shows that if other countries have as many as charging infrastructures per 100,000 inhabitants Norway does then on average they can increase 15% of their EV market share in years. This table also includes the scenario if these selected countries manage to build at least one fourth (25%) of charging infrastructures per 100,000 inhabitants Norway does. The calculation breakdown is provided in Appendix 1

Table 6.8
Possible market share changes of selected countries after the impact of building different number of charging infrastructures. *Source: IEA (2016), ICCT*

Country	Current EV market share %	Increase of Market share % (if I is Equal)	Increase of Market share % (if I is 1/4)
Canada	0.4	15.3	2.9
Denmark	2.3	12.8	0.4
France	1.0	14.6	2.2
Germany	0.7	15.7	3.3
Italy	0.1	16.1	3.8
Japan	0.6	14.4	2.0
Netherlands	9.7	03.5	-
Portugal	0.7	15.1	2.7
Spain	0.2	16.0	3.7
Sweden	2.4	14.4	2.0
United Kingdom	1.0	14.6	2.3
United States	0.7	15.3	2.9

***Note: Only publicly accessible charging infrastructures (both slow and fast charging outlets) has been considered*

Equal: *If the countries have as many as charging infrastructures per 100,000 inhabitants Norway does*

(1/4): *if countries have 25% of number of charging infrastructure per 100,000 inhabitants Norway does*

The numbers of publicly accessible charging infrastructures per million inhabitants are 309 and 1082 for Denmark and Netherland respectively. That's why in Denmark and Netherland different results than other countries in table 6.8.

As already mentioned that to be more specific for any specific country, the value of $\beta_1-\beta_6$ can be calculated based on that specific country's available data. Due to lack of data availability of China market, the impact of charging infrastructure on US market (though data is not even enough; only 11 observations) has been examined by conducting regression analysis. The result come up with $R^2 = .956$, adjusted $R^2 = .951$ and P-value $< .005$. The parameter of the variable is 12.269, which means every one charging infrastructures setup can increase EV sales by around 12 units in USA. SPSS results are shown in table 6.9

Table 6.9
SPSS results for regression analysis

Model Summary				
Model	R	R Square	Adjusted R Square	Sig. F changes
1	.978	.956	.951	.000

Coefficient				
Model	Unstandardized B	Coefficient Std. Error	t	Sig.
(Constant)	-12307.928	11766.138	-1.046	.323
USA charging Infrastructure	12.269	.874	14.037	.000

Table 6.10 displays the EV stock target of selected countries along with the calculation that if these countries manage to reach their EV target then what affect it will have on crude oil demand. Only 14 countries have been accounted for in calculating the result drawn in table 6.10. According to IEA study, the bright side is that if 2015 global growth rate of EV stock is maintained, then EV stocks will manage to exceed the 2020 EV stock target for many countries. Alone achieving the 2020 EV stock target of the selected countries will result crude oil demand to reduce by 0.33 million barrels per day. Thus, it is certain that if current growth rate of global EV sales remain for next few years or if there is increase in growth rate, then the global crude oil demand will reduce even more than the result shown in table 6.10.

Table 6.10

Projection of fall of crude oil demand if listed countries managed to meet their EV stock target in 2020; Source: (IEA, 2016)

Countries	2020 EV stock Target (millions vehicles)	Total EV total stocks (million vehicles)	Reduction in fuel consumption (mb/d)	Reduction in crude oil demand (mb/d)
Austria	0.2	13.10	0.10	0.33
China*	4.6			
Denmark	0.2			
France	2			
Germany	1			
India	0.3			
Ireland	0.1			
Japan	1			
Netherland	0.3			
Portugal	0.2			
South Korea	0.2			
Spain	0.2			
United Kingdom	1.6			
Unites State**	1.2			

Note:

* China's target includes 4.3 million cars and 0.3 million taxis and this target is part of an overall deployment target of 5 million cars, taxis, buses and special vehicles by 2020.

** This target number refers to the estimation based on the achievement of the 3.3 million electric vehicle target announced to 2025 in eight USA states.

The 'EVI 20 by 20' target aims at electric car fleet of 20 million globally by 2020. 20 million electric car on the road will reduce crude oil demand by almost 0.49 million barrels per day globally¹⁶. On the other side, according to Bloomberg New Energy Finance, in 2014 oil crisis was triggered as a result of 2 million barrels per day oil gluts. Mathematically, if the global electric car fleet reaches 80 million then it will reduce global crude oil demand by 2 million barrels per day. Moreover, According to IEA (2016), the Paris Declaration on Electro-Mobility and Climate Change and Call to Action sets a target of deploying 100 million electric car fleet and 400 million electric 2- and 3- wheelers by 2030. IEA 2DS aims at even more ambitious deployment pathway; IEA 2DS aims at deploying of 150 million electric car fleet by 2030. If the target of deploying 100 million electric cars is met by 2030 then alone electric car fleet is able to bring another crude oil crisis as a result of reducing more than crude oil demand by 2 million barrels per day.

Last 10 years, from 2005 to 2015, the average year-over-year electric car stock growth is 110% while for last 5 years, from 2010 to 2015, average year-over-year electric car stock growth 160%. If the EV stock forecast form coming years is conduct based on 78% which is year-over-year growth rate in 2015, it may deem very aggressive forecast. Therefore in this research paper, an EV stock forecast is conducted based on annual growth rate 50% and Bloomberg New Energy Finance's (BNEF) estimated growth rate 30%.

Bloomberg New Energy Finance (BNEF) belief the widespread adoption of EV mostly depends on the price which can be in effect by cost-efficient technological improvements and/or Governments initiatives, e.g. incentives to lower price. But they didn't mention explicitly the importance of other policy measures: charging infrastructures (I), user incentives (U), allowing EV to access facilities (W), communication process (C) and availability of different EV brands (A).

Fig 6.10 shows that if EV stock increases with 30% annual growth rate then the crude oil demand will fall 2 million barrels per day by 2030 while if EV stock increases with 50% annual growth rate then it the crude oil demand will fall 2 million barrels per day by 2026. Thus, there is possibility that within 2030 there will be oil glut of 2 million barrels per day which is equivalent to what triggered the 2014 oil crisis (Randall, 2016).

¹⁶ Calculation : $(20 \text{ million EV} * \kappa) * \rho$

Table 6.7 has already illustrated that only a single policy measure can change the market share largely; 3%-15% depending on building different numbers of charging infrastructures. So, it is certain that if the countries adopt similar Norwegian EV policy measures and/or policy measures included in EVMS model to increase market share, then the EV market share will increase more rapidly and the curves in fig 6.10 will be steeper resulting next oil crisis to happen earlier than expected.

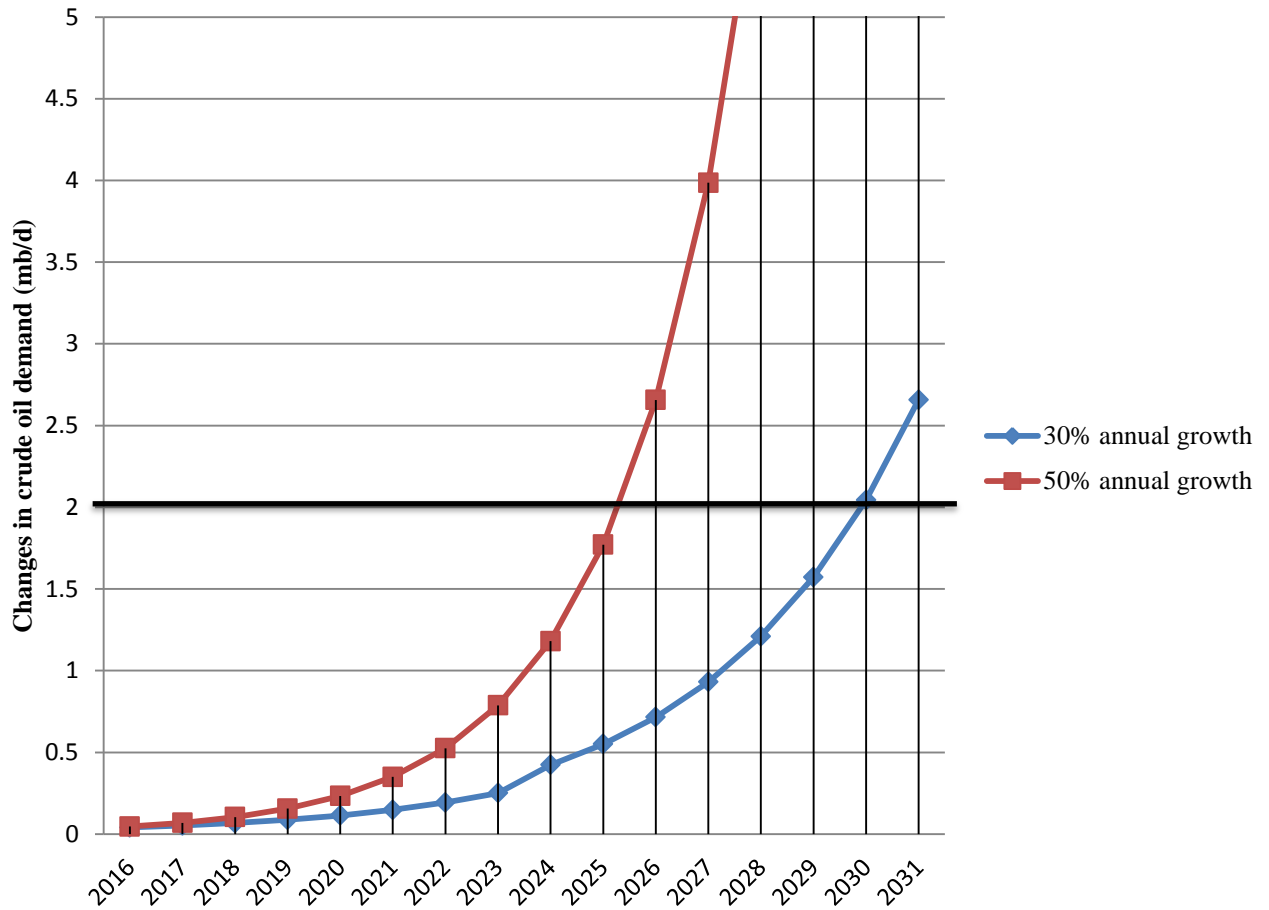


Figure 6.10: Prediction of the next oil crisis based on EV stocks globally; Source: EV stock data from IEA (2016)

Chapter 7: Conclusion

7.1 Conclusion

This chapter starts with the summary of the thesis. Afterwards, it includes the implications and concludes with the recommendation of future research scopes.

7.1.1 Summary

The research analysis of this thesis has developed electric vehicle market share (EVMS) model that combines all the necessary electric vehicle policy measures to increase the electric vehicle market share of a country. The included policy measurers are purchase incentive, P, use incentives, U, waiver on access restrictions, W, charging infrastructures, I, communication process, C, and availability of different electric vehicle brands, A. EVMS can be used by the policy makers to control the EV market shares by enforcing influential electric vehicle policy measures. Besides quantitative analysis of the significant influence of electric vehicle purchase incentives and building charging infrastructures, the importance of communication process, C, and availability of different electric vehicle brands, A, are emphasized descriptively in this thesis. User incentives, U, and Waiver to accesses, W, have comparatively small contribution to EV market share but not negligible. Depending on the population and traffic density it can impact differently, e.g. in densely populated cities access to bus lane facilities and free parking service may consider as significant incentives.

From the perspective of electric vehicle (EV) market growth both China and Norway possess high growth but the in size China is far larger than Norwegian EV market. Norwegian EV policy is praised globally for its effectiveness in adopting EV market rapidly and consistently. China is investing massively nationwide for green driving, though studies suggest that yet China needs to upgrade its EV policy measures to some extent in order to accomplish its set targets in time. Thorough analysis and comparison with Norwegian EV policy measures figure out the specific aspects of China's EV policy that need to be paid more attention, e.g. charging infrastructures, I, purchase incentives, P, communication process, C, user incentives, U. Theoretical models, e.g. Rogers (1983) diffusion of innovation theory, transport economic theories correspondingly support that China needs to upgrade its EV policy if it plans heading towards mass green driving. The research analysis of this thesis quantified the possible EV market share (of all new passenger cars) changes that can happen if China improves their EV policies to some extent, e.g. if China has as many as publicly accessible charging infrastructures per 100,000 inhabitants Norway does, holding all other factor constant, alone charging infrastructures can increase the EV market share by 16%

while if China has equivalent purchase incentives for EVs as Norway, holding all other factors constant China can increase EV market share by 0.9%. Previous studies, journal publication, and also analysis results from this research show that China needs to invest significantly in building charging infrastructures and national-level purchase incentives. It needs to be noted that China has target to deploy 0.5 million public chargers for cars by 2020 which is close to the estimated numbers of publicly accessible charging infrastructures (470,328) if China builds at least one fourth (1/4) of publicly accessible charging infrastructures Norway has per 100,000 inhabitants. Only by building that 470,328 publicly accessible charging infrastructures China can manage to increase the EV market share by 4%. This thesis analysis suggests that China can increase their EV market share of all new passenger cars up to 17.7% by introducing as much as purchase incentives, P, Norway does, building as many as charging infrastructures, I, as Norway does, and introducing same use incentives, U, wavier access, W, for EVs as Norway does. Moreover, the research analysis emphasizes that China needs to enhance its communication process through different channels and also to promote availability of different EV brands through the country to satisfy the demands of EV buyers.

The automotive market of China is growing rapidly. Its automotive market had growth even when the rest of the world had negative growth in 2015. The growth in automotive market leads to increase in oil demand. Therefore, apparently the more rapid growth in EV market the better China can handle its oil demand. Thus, upgrading EV policy measures is apparently necessary for China. Recently, Norwegian EV policy stands as the best available example. The investment volume and enthusiasm suggest that China has capitalization ability to adopt similar Norwegian EV policy measures. The magnitude (China accounts for 44.63% of global new registered BEVs in 2015) and prospect of China EV market (average year-over-year EV stock growth for last 5 years is around 200%) make it certain that in coming years EVs will have great impact on its fuel consumption which eventually will impact its crude oil demand. Both descriptive and quantitative analysis results demonstrate that by adopting similar Norwegian EV policy (e.g. as many as charging infrastructures, as much as purchase incentives, user incentives, access to bus lane), only the electric vehicle passenger cars can cut off a big portion of annual increase of China's oil demand. By adopting similar Norwegian EV policy measures China can manage to reduce oil demand by 0.90 million barrels per day by 2022 (based on EV stock) that represents 8.18% of 11.97 million barrels per day which was China's oil demand in 2015. On the other side, if Chinese electric vehicle

market follows market share forecast by Autofacts (2016), then China would manage to cut off oil demand by only 0.15 million barrels per day by 2022 (based on EV stock). Thus, the significant impact of Norwegian EV policy measures is vividly noticeable. Even though China's EV stocks percentage against total passenger cars is yet far below than 1% (only 0.182%) but if China keeps high growth by adopting similar Norwegian EV policy measures then within next few years it will manage to have healthier EV stock percentage against passenger car stock. By achieving 2% EV stock of all passenger car stocks by 2035, China can cut off oil demand by 0.47 million barrels per day and can cut off 1.17 million barrels per day by achieving 5% EV stocks of all passenger cars stock. Thus, it can be concluded that electric vehicle passenger cars in China alone are able to bring next oil crisis. The descriptive evidence and quantified impact of different policy measures calculated by EVMS model asserts that by adopting similar Norwegian EV policy measures China can achieve the 2% EV stock before 2035, or even possibility of reaching 5% can't be denied.

There are lots of speculations about the growth of global EVs and their impact on global crude oil demand; both high expectation and low expectation exists. This research analysis finds that even if only the number of electric passenger cars increase at certain pace (30% or 50% annual growth) then there will be oil glut of 2 million barrels per day by 2026 (50% growth) or 2030 (30% growth). It is significant fact as in 2014 the oil crisis was triggered by the same amount of oil glut, 2 million barrels per day. This research paper demonstrates that by adopting effective EV policy may result increase of EV market share beyond expectation which eventually may cause massive reduction in crude oil demand earlier than 2030.

7.1.2 Implications

The findings by this study are of interest to EV policy makers from any countries, EV manufacturers and oil industry. Even though most of the discussion and analysis are based on China and Norwegian EV market, the findings can be helpful for other countries as well as to understand what policy measures require most attention. EVMS model combines all necessary EV policy measures to change the EV market share. To my knowledge, no other previous studies related to EV policy measures hasn't established such model that accounts for combination of all significant EV policy measures to calculate the market share changes. It is believed that the EVMS model will not only help China but also any other country. Policy makers can use EVMS model to control and influence their EV market shares. Along with EV policy measurers, the policy makers also need to focus on national-grid system to support the load of electric charging of EVs.

Generous EV policy measures are significantly important for the automotive industry. Already discussed that still the EVs have high price tags, still we don't have enough charging infrastructures, and to divert the buyers from ICE vehicles to EVs there is need to advantage the EV buyers by providing some use incentives as well as giving access to restricted zones or systems. Only generous, effective EV policy measures have solution to all of these issues. Therefore, the more effective the EV policy is the more potential the EV prospects will be. The potential prospect of EV market will motivate the automotive manufacturers to invest more in R&D and technological development. Thus, EV policy measures can influence the automotive industry, particularly the EV manufacturers. Alike circle influence, afterwards EV buyers will get more models and brand available from enthusiastic automotive industry.

On the other hand, Generous EV policy measures can affect the global environment as well. As EVs are GHG emission free, they are considered as solution to global climate change. So, high growth of EV is significantly important for better global environment and high growth of EV relies on effective EV policy measures. Though, it needs to note that fuel used for electricity production is also important factor to be considered. Sustainable energy sources need to be developed for promoting full green drive. Still the major source of energy production in China is coal. So, it is true that in China EV cannot be fully green drive until or unless China significantly reduces its coal usage, but until then EVs can reduce at least the local environmental (both air and sound) pollution.

The widespread increase of EV sales also concern for oil industry. Transport sector is responsible for consuming large portion of oil supplies. Therefore, the more EV sales will cause the less oil demand. The less oil demand leads to oil surplus which results the fall of oil price. Thus, the increase number of EVs can lead to oil crisis and collapse of oil industry. Therefore, the possible magnitude of crude oil demand changes in near future due to EVs is important concern for oil industry. In such crisis, the petroleum producing companies or countries can diversify their business and invest more in new industries, especially renewable energies.

7.2 Future research scope

The growth of EV market share is expected to be higher and brisk in coming years, but the expectation is mostly based on the fact that manufacturers are improving technical performance and efficiently trying to the lowering cost for EVs, but after having thorough study it has been figured out that the market share of EV can increase even more rapidly than

expectation if policy makers pay more focus in communication process or public awareness and availability of more EV brands. These two policy measures have been included in the modeling for EV market share (EVMS) but were not quantified. The necessities of these two policy measurers have been already discussed in this research based on previous studies, journal publications. Therefore, it is necessary to conduct further research on these two policy measures to quantify them in order to adjust them in EV market share modeling for greater use.

Moreover, further research can conduct to analyze the crude oil demand changes due to EVs including all types of vehicles, e.g. passenger cars, buses, trucks, bikes etc.

This research was mostly about how China can improve their EV market share by adopting effective EV policy measures and their impact on crude oil demand but further research can consider deriving evidence from other countries where car population is high and their market can influence their global scenarios, e.g. India and USA.

Bibliography

- Amsterdam Roundtable and McKinsey & Company. (2014, April). *Evolution; Electric Vehicles in Europe: gearing up for a new phase?* Amsterdam: Amsterdam Roundtable Foundation.
- An, D. F. (2016). China's NEV Policies and Market Development. *Industrial Upgrading and Economic Growth in China Conference*. Michigan: Innovation Center for Energy and Transportation(iCET).
- Archer, M., Decoteau, C., Gorski, P., Little, D., Porpora, D., Rutzou, T., et al. (2016, December 23). *What is critical realism*. Retrieved April 22, 2017, from <http://www.asatheory.org/current-newsletter-online/what-is-critical-realism>
- Autofacts. (2016, September). *Can alternative vehicles sales grow without incentives?* Retrieved April 2, 2017, from http://www.pwc.com/kr/ko/industries/automotive/201609_autofacts_china_en.pdf
- Axsen, J., & Kurani, K. S. (2012). Interpersonal influence within car buyers' social networks: applying five perspectives to plug-in hybrid vehicle drivers. *Environmental and Planning A*, 1047-1065.
- Ayre, J. (2016, May 21). *Excerpts From Interview Elon Musk Gave To Norwegian EV Association*. Retrieved April 1, 2017, from <https://cleantechnica.com/2016/05/21/excerpts-interview-elon-musk-gave-norwegian-ev-association/>
- Badkar, M. (2013, August 07). *Elon Musk's Answer To A Question About Tesla's Competition: 'HAHAHAHAHAHA'*. Retrieved March 16, 2017, from <http://www.businessinsider.com/elon-musk-response-to-bmw-i3-2013-8?r=US&IR=T&IR=T>
- Bakker, S., & Trip, J. J. (2013). Policy options to support the adoption of electric vehicles in the urban environment. *Transportation Research Part D* 25, 18-23.
- Bellona Europa. (2015, March). *Electric Vehicles: The Norwegian Experience in Overcoming Barriers*. Retrieved March 15, 2017, from http://bellona.org/assets/sites/3/BellonaBrief_EV-Norwegian-Success-Story.pdf
- Bjerkan, K. Y., Nørbech, T. E., & Nordtømme, M. E. (2016). Incentives for promoting Battery Electric Vehicles (BEV) adoption in Norway. *Transportation Research Part D*, 169-180.
- Boslaugh, S. (2007). *Secondary Data Sources for Public Health: A Practical Guide*. New York: Cambridge University Press.
- BP. (2016). *BP Energy Outlook 2016*. London: BP p.l.c.
- BP. (2016). *BP Statistical Review 2016: China's energy market in 2015*. London: BP p.l.c.

- BP. (2016). *BP Statistical Review of World Energy 2016*. London: BP p.l.c.
- Business Wire. (2015, December 23). *The World's Largest Electric Vehicle Maker Also Has a US Presence*. Retrieved March 21, 2017, from <http://www.businesswire.com/news/home/20151223005656/en/World%E2%80%99s-Largest-Electric-Vehicle-Maker-Presence>
- Button, K. (2014). *Transport Economics (3rd Edition)*. Massachusetts: Edward Elgar Publishing, Inc.
- CAA. (2017). *Types of Electric Vehicles*. Retrieved March 19, 2017, from <https://www.caa.ca/electric-vehicles/types-of-electric-vehicles/>
- CAAM. (2016, January 20). *New energy vehicles enjoyed a high-speed growth*. Retrieved February 12, 2017, from China Association of Automobile Manufacturers: <http://www.caam.org.cn/AutomotivesStatistics/20160120/1305184260.html>
- Campbell, D. T., & Stanley, J. C. (1966). Experimental and Quasi-Experimental Designs for Research. In *Experimental and Quasi-Experimental Designs for Research* (p. 05). Houghton Mifflin Company.
- China Auto web. *Chinese-Made Electric Cars*. Retrieved March 29, 2017, from <http://chinaautoweb.com/electric-cars/>
- China Statistics Press. (2017). *China Statistical yearbook 2016*. Retrieved January 25, 2017, from <http://www.stats.gov.cn/english/statisticaldata/AnnualData/>
- Collins, G., & J.D. (2016). *China's Evolving Oil Demand: Slowing Overall Growth, Gasoline Replacing Diesel as Demand Driver, Refined Product Exports Rising Substantially*. Retrieved March 12, 2017, from <http://www.bakerinstitute.org/media/files/files/e0b5a496/WorkingPaper-ChinaOil-093016.pdf>
- Dargay, J., Gately, D., & Sommer, M. (2007). Vehicle Ownership and Income Growth, Worldwide: 1960-2030. *Energy Journal* (28), 143-170
- Ding, Y., Shen, W., Yang, S., Han, W., & Chai, Q. (2013). Car dieselization: A solution to China's energy security? *Energy Policy* (62), 540-549.
- Easterby-Smith, M., Thrope, R., & Jackson, P. (2012). *Management Research (4th edition)*. SAGE.
- Economist. (2017, February 18). Electric Cars: Volts Wagons. p. 53.
- EPA. (2017). *Overview of Greenhouse Gases*. Retrieved March 30, 2017, from United States Environmental Protection Agency: <https://www.epa.gov/ghgemissions/overview-greenhouse-gases>

- Evolita. Retrieved February 10, 2017, from <http://beta.evolita.com/explore/top-20-selling-car-models-in-china-2015/j2lbz/>
- Fearnley, N., Pfaffenbichler, P., Figenbaum, E., & Jellinek, R. (2015). *E-vehicle policies and incentives - assessment and recommendations*. Oslo: TØI.
- Feijter, T. d., Wang, J., & Ning., W. (n.d.). *China electric cars*. Retrieved February 10, 2017, from <https://www.carnewschina.com/category/green-news/>
- Figenbaum, E., & Kolbenstvedt, M. (2015). *Pathways to electromobility - perspectives based on Norwegian experiences*. Oslo, Norway: Institute of Transport Economics (TØI).
- Figenbaum, E., Assum, T., & Kolbenstvedt, M. (2015). Electromobility in Norway: Experience and Opportunities. *Research in Transportation Economics* (50), 29-38.
- Gissler, A., Raab, C., Tix, M., & Merk, S. (2016). *Electric Vehicle Market Attractiveness; Unraveling Challenges and Opportunities*. Accenture .
- Global Petrol Price. (2015, October 7). *Breakdown of oil consumption by sector*. Retrieved March 20, 2017, from <http://www.globalpetrolprices.com/articles/39/>
- Gomez Vilchez, J. J., Jochem, P., & Fichtner, W. (2013). *The Impact of Electric Vehicles on the Global Oil Demand and CO2 Emission*. Retrieved January 22, 2017, from <http://www.wctrs.leeds.ac.uk/wp/wp-content/uploads/abstracts/rio/general/1659.pdf>
- Greene, D. L., & Liu, C. (2014). *Transition to Electric Drive Vehicles: Public Policy Implications of Uncertainty, Network Externalities, Tipping Points and Imperfect Markets*. Knoxville: Howard H. Baker Jr. Center for Pulic Policy.
- Greene, D. L., Park, S., & Liu, C. (2013). *Analyzing the Transition to Electric Drive in California*. Knoxville: Howard H. Baker Jr. Center for Pulic Policy.
- Haig, B. D. (2013). The Philosophy of Quantitative Methods. In P. E. Nathan, & T. D. Little, *The Oxford Handbook of Quantitative Methods; Volume 1 : Foundations* (pp. 7-31). New York: Oxford University Press, Inc.
- Hao, H., Ou, X., Du, J., Wang, H., & Ouyang, M. (2014). China's electric vehicle subsidy scheme: Rationale and impacts. *Energy policy* (73), 722-732.
- Hao, H., Wang, H., Ouyang, M., & Cheng, F. (2011). Vehicle survival patterns in China. *Science China Technological Sciences*, 54, 625–629.
- Haugneland, P., Bu, C., & Hauge, E. (2016, June 19-22). *The Norwegian EV success continues*. Retrieved January 27, 2017, from <http://wpstatic.idium.no/elbil.no/2016/06/paper-evs29-norwegian-ev-success.pdf>
- Hirsh, E., Jullens, J., Singh, A., & Wilk, R. (2016). *2016 Auto Industry Trends: Automakers and suppliers can no longer sit out the industry's transformation*. PwC.

- Holtmark, B., & Skonhoft, A. (2014). The Norwegian support and subsidy policy of electric cars. Should it be adopted by other countries? *Environmental science and policy* (42), 160-168.
- Hyndman, R. J., & Athanasopoulos, G. (2012, May). *Forecasting: principles and practice*. Retrieved March 30, 2017, from <https://www.otexts.org/fpp>
- ICCT. (2013). *Renewed and Enhanced subsidies for energy-efficient vehicle in China*. International Council on Clean Transportation.
- iCET. (2016). *China Consumer EV Choice Preference; Study Brief*. Beijing: Innovation Center for Energy and Transportation.
- IEA. (2011). *World Energy Outlook 2011*. Paris: International Energy Agency.
- IEA. (2016). *Global EV outlook 2016*. Paris: International Energy Agency.
- Ito, N., Takeuchi, K., & Managi, S. (2013). Willingness-to-pay for infrastructure investments for alternative fuel vehicles. *Transport Research Part D* (18), 1-8.
- Jin, L., & Slowik, P. (2017). *Literature review of electric vehicle consumer awareness and outreach activities*. icct.
- Jolly, D. (2015, October 15). *Norway Is a Model for Encouraging Electric Car Sales*. Retrieved March 31, 2017, from https://www.nytimes.com/2015/10/17/business/international/norway-is-global-model-for-encouraging-sales-of-electric-cars.html?_r=0
- Jørgensen, F., & Pedersen, P. (2004). Travel distance and optimal transport policy. *Transportation Research Part B - Methodological* 38 (5), 415-430.
- Kane, M. (2016). *Norway passes 100,000 All-Electric Vehicles on the road today*. Retrieved April 5, 2017, from <http://insideevs.com/norway-passes-100000-all-electric-vehicles-on-the-road-today/>
- Keat, R., & Urry, J. (2011). *Social Theory as Science*. Routledge.
- Krieger, A., Radtke, P., & Wang, L. (2012, July). *Recharging China's electric-vehicle aspirations*. Retrieved February 1, 2017, from <http://www.mckinsey.com/industries/automotive-and-assembly/our-insights/recharging-chinas-electric-vehicle-aspirations>
- Larson, P. D., Viáfara, J., Parsons, R. V., & Elias, A. (2014). Consumer attitudes about electric cars: Pricing analysis and policy implications. *Transportation Research Part A* 69, 299-314.
- Little, D. (2008, May 08). *Realism for the social sciences?* Retrieved April 22, 2017, from [Understandingsociety.blogspot.no](http://understandingsociety.blogspot.no): <http://understandingsociety.blogspot.no/2008/05/realism-for-social-sciences.html>

- Little, D. (2013, March 14). *What is "critical" about critical realism*. Retrieved April 22, 2017, from <http://understandingsociety.blogspot.no/2013/03/what-is-about-critical-realism.html>
- Lutsey, N. (2015). *Transisition to a global zero-emission vehicel fleet: A collaborative agenda for government*. ICCT.
- Marro, N., Liu, H., & Yan, Y. (2015, February 2). *Opportunities and Challenges in China's Electric Vehicle Market*. Retrieved February 24, 2017, from <https://www.chinabusinessreview.com/opportunities-and-challenges-in-chinas-electric-vehicle-market/>
- Mathisen, T. A. (2005). The theory of science in transport economics. Chapter in Vitenskapsteoretiske essays i tilknytning til forskningsprosjekter ved Handelshøgskolen i Bodø Ed. Gilje, N. and Ingebrigtsen, S. *HHB Working paper no. 11/2005*.
- Mathisen, T. A. (2008). *Public Passenger Transport in Norway*. Bodø: Bodø Graduate School of Business.
- Matulka, R. (2014, September 15). *The History of the Electric Car*. Retrieved March 21, 2017, from <https://www.energy.gov/articles/history-electric-car>
- Mendenhall, W., & Sincich, T. (2012). Introduction to time series modeling and forecasting. In *A Second Course in Statistics: Regression Analysis (7th Edition)* (p. 519). Boston: Pearson Education, Inc.
- Mock , P., & Yang, Z. (2014). *Driving Electrifications: a global comparison of fiscal incentive policies for electic vehicles*. ICCT.
- Morris, M. (2013, January). *Constant Consideration:Brand Choice on the Path*. Retrieved may 04, 2017, from <https://www.thinkwithgoogle.com/articles/constant-consideration-new-vehicle-study.html>
- Myklebust, B. (2013, November 17-20). *EVs in bus lanes – controversial incentive*. Retrieved March 31, 2017, from http://e-mobility-nsr.eu/fileadmin/user_upload/downloads/info-pool/EVs_in_bus_lane_Benjamin_Myklebust_ZERO_EVS27.pdf
- Nationa Research Council. (2013). *Transition to alternative fuels and vehicles*. Retrieved March 3, 2017, from <https://www.nap.edu/read/18264/chapter/1>
- Nau, R. (2017). *Statistical forecasting:notes on regression and time series analysis*. Retrieved March 24, 2017, from <http://people.duke.edu/~rnau/411home.htm>
- Norsk ebilforening. (2017, March 31). *Norwegian EV market*. Retrieved January 26, 2017, from <http://elbil.no/english/norwegian-ev-market/>

- Norwegian Water Resources and Energy Directorate. (2016, July 5). *Electricity disclosure 2015*. Retrieved March 31, 2017, from <https://www.nve.no/energy-market-and-regulation/retail-market/electricity-disclosure-2015/>
- OICA. (2017). *2005-2016 Sales Statistics*. Retrieved March 23, 2017, from <http://www.oica.net/category/sales-statistics/>
- Olczak, N. (2015, November 17). *China remains a rocky road for electric cars*. Retrieved February 23, 2017, from <https://www.chinadialogue.net/article/show/single/en/8302-China-remains-a-rocky-road-for-electric-cars>
- Petschnig, M., Heidenreich, S., & Spieth, P. (2014). Innovative alternatives take action - Investigating determinants of alternative fuel vehicle adoption. *Transportation Research Part A: Policy and Practice* 61, 68-83.
- Pontes, J. (2015, December 28). *World Top 10 November 2015 (Updated)*. Retrieved March 21, 2017, from <http://ev-sales.blogspot.no/2015/12/world-top-10-november-2015.html>
- Pontes, J. (2017, January 25). *China Electric Car Sales — BYD Wins 2016, Geely Emgrand EV Wins December*. Retrieved February 10, 2017, from <https://evobsession.com/china-electric-car-sales-byd-wins-2016-geely-emgrand-ev-wins-december/>
- Randall, T. (2016, February 25). *Here's How Electric Cars Will Cause the Next Oil Crisis*. Retrieved March 20, 2017, from <https://www.bloomberg.com/features/2016-ev-oil-crisis/>
- Reuters. (2015, March 19). *Branson says Virgin working on electric cars: Bloomberg TV*. Retrieved March 20, 2017, from <http://www.reuters.com/article/us-virgin-electriccar-idUSKBN0MF27P20150319>
- Rogers, E. M. (1983). *Diffusion of Innovation (3rd Edition)*. New York: The Free Press.
- Schmitt, B. (2016, February 1). *Large Number Of Chinese EV Sales Fake, Investigators Say*. Retrieved March 30, 2017, from <https://www.forbes.com/sites/bertelschmitt/2016/02/01/large-number-of-chinese-ev-sales-fake-investigators-say/#250eb5456ae1>
- Serafimova, T. (2015). *Electric Vehicles: The Norwegian Experience in Overcoming Barriers*. Brussels : Ellona Europa.
- Shirouzu , N., & Lienert, P. (2015, October 28). *China and Japan are battling over the future of electric cars*. Retrieved March 21, 2017, from <http://www.businessinsider.com/r-auto-power-play-japans-hydrogen-car-vs-chinas-battery-drive-2015-10?r=US&IR=T&IR=T>
- Shuttleworth, M. (2009, November 8). *Types of Validity*. Retrieved May 01, 2017, from <https://explorable.com/types-of-validity?gid=1579>

- Sierzchula, W., Bakker, S., Maat, K., & Wee, B. V. (2014). The influence of financial incentives and other socio-economic factors on electric vehicle adoption. *Energy Policy* 68, 183-194.
- Simonof, J. S. (2016). *Regression — the basics*. Retrieved March 30, 2017, from <http://people.stern.nyu.edu/jsimonof/classes/2301/pdf/regmback.pdf>
- Slowik, P., & Lutsey, N. (2016). *Evolution of incentives to sustain the transition to a global electric vehicle fleet*. ICCT.
- Smouse, B. (2015, June 30). *Study: New car buyers staying loyal to old brands*. Retrieved May 12, 2017, from <https://www.usatoday.com/story/money/cars/2015/06/30/car-buyers-higher-brand-loyalty-rates/29491029/>
- SSB. (2017a). *Registered vehicles*. Retrieved February 21, 2017, from <https://www.ssb.no/en/transport-og-reiseliv>
- SSB. (2017b). *Population and population changes*. Retrieved February 25, 2017, from <https://www.ssb.no/en/befolkning>
- Statista. (2017). *Vehicle population in China from 2007 to 2015*. Retrieved February 21, 2017, from <https://www.statista.com/statistics/285306/number-of-car-owners-in-china/>
- Tan, Q., Wang, M., Deng, Y., Yang, H., Rao, R., & Zhang, X. (2014). *The Cultivation of Electric Vehicles Market in China: Dilemma and Solution*. Basel: MDPI.
- Tang, B.-j., Wu, X.-f., & Zhang, X. (2013). Modeling the CO2 emission and energy saved from new energy vehicles based in the logistic-curve. *Energy policy* (57), 30-35.
- The Global Economy. (2017). *Passenger car sales - country rankings*. Retrieved February 21, 2017, from http://www.theglobaleconomy.com/rankings/passenger_cars_sales/#China
- The World Bank. (2017). *World Development Indicators database: Population 2015*. Retrieved March 12, 2017, from <http://databank.worldbank.org/data/download/POP.pdf>
- U.S. Department of Energy. (2014, September 15). *The History of the Electric Car*. Retrieved March 21, 2017, from <https://www.energy.gov/articles/history-electric-car>
- U.S. Department of Energy. *Alternative Fuels Data Center*. Retrieved March 19, 2017, from http://www.afdc.energy.gov/vehicles/electric_basics_ev.html
- Unger, S. (2015). The impact of e-car deployment on global crude oil demand. *OPEC Energy Review*, 402-417.
- Wang, Y., Teter, J., & Sperling, D. (2012). Will China's Vehicle Population grow even faster than forecasted? *Energy Policy* 39(6), 3296–3306.

- Wooldridge, J. M. (2012). *Introductory Econometrics*. Mason, OH, USA: South-Western, Cengage Learning .
- Workman, D. (2017, March 14). *Crude Oil Imports by Country*. Retrieved April 20, 2017, from <http://www.worldstopexports.com/crude-oil-imports-by-country/>
- Yale Environment 360. (2011, May 04). *Nissan's Carlos Ghosn Seeks Revenge for the Electric Car*. Retrieved March 17, 2017, from http://e360.yale.edu/features/nissans_carlos_ghosn_seeks_revenge_for_the_electric_car
- Yang, Z. (2016, May 18). *2015 Global electric vehicle trends: Which markets are up (the most)*. Retrieved February 21, 2017, from <http://www.theicct.org/blogs/staff/2015-global-electric-vehicle-trends>
- Yang, Z., Slowik, P., Lutsey, N., & Searle, S. (2016). *Principles for effective electric vehicles incentive design*. Washington: International council on clean transportation.
- Ying, T. (2016, December 8). *China's Car Sales Have Been on a 26-Year Record Streak*. Retrieved April 13, 2017, from <https://www.bloomberg.com/news/articles/2016-12-08/china-wraps-up-26th-straight-car-sales-record-with-month-to-go>
- Zhang, Y., Yu, Y., & Zou, B. (2011). Analyzing public awareness and acceptance of alternative fuel vehicles in China: The case of EV. *Energy Policy* 39, 7015-7024.
- Zheng, J., Mehndiratta, S., Guo, J. Y., & Liu, Z. (2012). Strategic policies and demonstration program of electric vehicle in China. *Transport Policy* 19, 17-25.

Appendices

Appendix 1: Tables and Figures

All tables of particular importance are included in this appendix.

Table

Table 1 Top 10 countries with oil consumption, 2015	108
Table 2 List top 10 oil importing countries	108
Table 3 List of top 10 countries with CO2 emission, 2011	109
Table 4 New passenger car sales for each year, 2005-2015	109
Table 5 Descriptive Statistics of data set China's conventional passenger cars (2005-2015) and difference by lagged by one period	110
Table 6 Average scores for top 10 policy measures on their effectiveness, efficiency, and their feasibility	110
Table 7 Publicly accessible charging infrastructure stocks per million inhabitants for selective countries, (up to 2015)	111
Table 8 Forecast of number of new passenger cars in China using ARIMA (0, 1, 0) with drift, 2017-2035	112
Table 9 Forecast of numbers (in thousand) of new EVs sales for each years based on different scenarios, 2017-2022	112
Table 10 Global EV stocks for each year, 2005-2015	113
Table 11 Charging Infrastructure stocks and market shares for USA, 2007-2015	113

Figure

Figure 1 Calculation breakdown of table 6.8	111
--	------------

Table 1**Top 10 countries with oil consumption, 2015: Source: (BP, 2016)**

Countries	Oil consumption (million barrels per day)
United states	19.40
China	11.97
India	4.16
Japan	4.15
Saudi Arabia	3.90
Brazil	3.16
Russia	3.11
South Korea	2.58
Germany	2.34
Canada	2.32

Table 2**List top 10 oil importing countries; Source: (Workman, 2017)**

Countries	Values of Import (\$)	Percentage of global crude oil imports
China	134.3 billion	16.7
United States	132.6 billion	16.5
India	72.3 billion	9
South Korea	55.1 billion	6.9
Japan	45 billion	5.6
Germany	36.4 billion	4.5
Netherlands	35.4 billion	4.4
Spain	24.8 billion	3.1
Italy	23.7 billion	3
France	22.9 billion	2.8

Table 3

List of top 10 countries with CO2 emission, 2011; Source: theglobaleconomy.com

Country	CO2 emission (in thousands of tonnes)
China	9,724,591
USA	5,305,280
India	1,846,764
Russia	1,768,073
Japan	1,191,056
Germany	732,120
Iran	619,166
South Korea	589,401
Indonesia	573,379
Saudi Arabia	500,729

Table 4

New passenger car sales for each year, 2005-2015;

Source: China year book 2016, Oica.net

Years	China	Rest of the world World-wide
2005	4,157,504	41,277,347
2006	4,678,667	42,628,551
2007	5,000,042	44,364,683
2008	6,226,814	43,061,497
2009	10,248,554	39,159,408
2010	12,546,891	41,857,323
2011	13,694,540	43,158,219
2012	15,248,801	45,175,209
2013	17,522,965	45,175,100
2014	19,366,787	45,709,703
2015	21,202,815	45,165,597

Table 5
Descriptive Statistics of data set China's conventional passenger cars (2005-2015) and difference by lagged by one period

	Data set from 2005-2015	Differences by lagged one period
Mean	11808580	1704531.1
Standard Error	1866669.408	332627.1011
Median	12546891	1695144.5
Standard Deviation	6191042.035	1051859.251
Sample Variance	3.8329E+13	1.10641E+12
Range	17045311	3700365
Minimum	4157504	321375
Maximum	23202815	4021740
Sum	129894380	17045311
Count	11	10

Table 6
Average scores for top 10 policy measures on their effectiveness, efficiency, and their feasibility, Source: Bakker et al., (2013)

	Policy measures	Average score	Effectiveness	Efficiency	Feasibility
1	Lobby for EU-wide standards for plugs and sockets	4.27	4.14	4.50	4.17
2	Charging Infrastructures	4.17	4.33	4.17	4.00
3	Show political leadership (e.g. EVs in fleet)	4.03	4.33	4.17	3.60
4	Support car-sharing initiatives with EVs	4.00	4.00	3.75	4.25
5	Providing information to businesses and consumers/ communication process	3.83	3.83	3.83	3.83
6	EV-readiness as a requirement for new property developments	3.74	4.00	3.83	3.40
7	Enable roaming between regions (billing)	3.63	3.86	3.71	3.33
8	Reserve on-street parking spaces for EVs	3.61	4.00	3.67	3.17
9	Exemption from toll fees	3.33	4.00	3.40	2.60
10	Allowing to drive on bus lanes	3.20	3.80	3.60	2.20

Table 7
Publicly accessible charging infrastructure stocks per million inhabitants for selective countries,
(up to 2015): Source: IEA (2016)

Countries	Publicly accessible charging infrastructure stocks per million inhabitants
Canada	98
Denmark	309
France	159
Germany	67
Italy	29
Japan	174
Netherlands	1084
Portugal	114
South Korea	26
Spain	35
Sweden	175
United Kingdom	155
United States	97
China	42
Norway	1372

Figure 1
Calculation breakdown of table 6.8

	Publicly Accessible EVSE per million inhabitants	Population ('000)	Publicly Accessible EVSE per 100,000 inhabitants	Norway (per 100,000)	Required to have as many as Norway	(1/4) of Norway (34.25)	Market Share Increase	Market Share Increase	market share in 2015
Canada	98	35,852	9.8	137.2	127.4	24.45	15.3%	2.9%	0.4
Denmark	309	5,676	30.9		106.3	3.35	12.8%	0.4%	
France	159	66,808	15.9		121.3	18.35	14.6%	2.2%	1.2
Germany	67	81,413	6.7		130.5	27.55	15.7%	3.3%	0.7
Italy	29	60,802	2.9		134.3	31.35	16.1%	3.8%	0.1
Japan	174	126,958	17.4		119.8	16.85	14.4%	2.0%	0.6
Netherlands	1084	16,937	108.4		28.8	-74.15	3.5%		9.7
Portugal	114	10,349	11.4		125.8	22.85	15.1%	2.7%	0.7
South Korea	26	50,617	2.6		134.6	31.65	16.2%	3.8%	
Spain	35	46,418	3.5		133.7	30.75	16.0%	3.7%	0.2
Sweden	175	9,799	17.5		119.7	16.75	14.4%	2.0%	2.4
United Kingdom	155	65,138	15.5		121.7	18.75	14.6%	2.3%	0.7
United States	97	321,419	9.7		127.5	24.55	15.3%	2.9%	0.7
China	42	1,371,220	4.2		133	30.05	16.0%	3.6%	1
Norway	1372	5,196	137.2						

Source: The World Bank (2017), IEA (2016)

Table 8
Forecast of number of new passenger cars in China using ARIMA (0, 1, 0) with drift, 2017-2035

Years	Forecast of number of new passenger cars in China
2017	24,611,877
2018	26,316,408
2019	28,020,939
2020	29,725,471
2021	31,430,002
2022	33,134,533
2023	34,839,064
2024	36,543,595
2025	38,248,126
2026	39,952,657
2027	41,657,188
2028	43,361,719
2029	45,066,250
2030	46,770,782
2031	48,475,313
2032	50,179,844
2033	51,884,375
2034	53,588,906
2035	55,293,437

Table 9
Forecast of numbers (in thousand) of new EVs sales for each years based on different scenarios, 2017-2022

	2017 ('000)	2018	2019	2020	2021	2022
Autofacts (2016)	563,612	713,175	888,264	1,052,282	1,219,484	1,388,337
Equal	4,919,914	5,371,179	5,847,970	6,313,690	6,782,594	7,253,149
(1/2)	2,820,521	3,126,389	3,457,784	3,778,107	4,101,615	4,426,774
(1/4)	1,836,046	2,073,733	2,336,946	2,589,089	2,844,415	3,101,392

Table 10
Global EV stocks for each year, 2005-2015; Source: IEA (2016)

Year	EV stocks (world-wide)
2005	1,670
2006	1,780
2007	1,790
2008	4,040
2009	5,890
2010	12,480
2011	60,650
2012	179,220
2013	383,090
2014	706,770
2015	1,256,910

Table 11
Charging Infrastructure stocks and market shares for USA, 2007-2015; Source: IEA (2016)

Years	Charging Infrastructure stocks	Market share (%)
2007	375	-
2008	381	-
2009	420	-
2010	542	0.0
2011	4392	0.1
2012	13159	0.4
2013	16867	0.6
2014	22633	0.7
2015	31674	0.7

Note: In 2007-2009 the EV market share was very small that can be considered negligible