A STUDY OF ELECTRIC VEHICLES' PROSPECTS IN CHINA

By

Jun, Byung-Keun

THESIS

Submitted to

KDI School of Public Policy and Management

In partial fulfillment of the requirements

for the degree of

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ABSTRACT

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Electric vehicle will replace oil consumption, improve the environment, and reduce greenhouse gases. As well, electric vehicles will determine the 21st-century landscape of the auto industry.

Electric vehicles also have crucial meaning for China. China has a high dependence on overseas oil resources, and many Chinese still suffer from pollution. In terms of industry aspects, the electric vehicle industry could be chance for China to become a world leader in a high-end industry. In China, the auto market could directly jump into battery electric vehicles (BEVs) bypassing the hybrid electric vehicle (HEV) and plug-in hybrid vehicle (PHEV) period. In this market, local Chinese auto maker will increase their sales share. The battery electric vehicle's industry supply chain model will be similar to cellular phone industry rather than the personal computer.

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Chapter 1. Introduction

In 2009, China's vehicle sales have outpaced those in the United States. And thousands of auto-maker from around the world put their cars on display in Shanghai last April. In fact, China has become the largest market in the auto industry.

As a result, auto-makers' prospects in the Chinese auto market, such as 'what kind of vehicle will be made in China,' and 'how many will it be sold in China,' are critical issues for the global automotive industry suffering during global economic recession. As well, vehicles' consumption patterns in China will determine energy security and environmental pollution in the world.

My research based on statistical data and professional reports in various fields, addresses the above critical issue. I investigated the merit of electric vehicles' and explain why electric vehicle could be a key means for China's government to achieve core policy goals. By analyzing major factors, I also predict how electric vehicles will be developed and deployed in China.

In 2006, McKinsey & Company estimated the future power train in vehicle in the work of "The Future of Automotive Power." McKinsey estimated that China's hybrid vehicle will develop as follows; 'Despite the Chinese government's push for hybrids in order to improve the automotive industry's image and spur the development of high-tech know-how, Chinese customers will stick with ICE gasoline. The reasons for this include

the country's low incomes, low fuel taxes, and a low level of environmental concern.' However, I have a different opinion. Chinese citizens' incomes are not just low any more. There are hundreds of millions high-incomers in China as well as hundreds of millions with low-incomers. Also, the Chinese government and people do not have less' concern for the environment than people of OECD countries. As well, China's tax system is not adverse to the adoption of electric vehicles.

In this research, I forecast that the future of electric vehicle is relatively bright. China has a high dependence on overseas oil resources. However, China has been improving the environment, and obtained a certain level of performance. However, there should be additional improvement, because many Chinese suffer from pollution. In terms of industry aspects, China is trying to use of the EV transition period to become a global leader in the auto industry.

This paper addresses the following three questions by considering major factors regarding the Chinese vehicle market. The first is 'Which model will prevail in China?' The second is, 'Could local Chinese auto maker be better in the next-generation vehicle market?' The last is, 'In the electric vehicle market, will the auto industry remain the same as before or Change?'

Chapter 2. What is the Electric Vehicles?

Types of an electric vehicle

In "electric drive", torque is supplied to the wheels by an electric motor that is powered either solely by a battery, or an internal combustion engine using hydrogen, gasoline or diesel, or, by a fuel cell.[1]

I will classify electric vehicle as three types; hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) according to how the "**I**nternal **C**ombustion **E**ngine (ICE)" and "Battery (Energy Storage System)" are combined. Although a fuel cell vehicle is also one kind of electric vehicle, I will not include that vehicle in this research, because the system characteristics are very different.

Table 1. The type of electric car

Type	Power	Energy source	Additional Infra.
Hybrid **E**lectric **V**ehicle(HEV)	Engine+ Motor	Gasoline	Nothing
Plug-in-**H**ybrid(PHEV)	Engine+ Motor	Gasoline + Electricity	Small
Battery **E**lectric **V**ehicle(BEV)	Motor	Electricity	Big

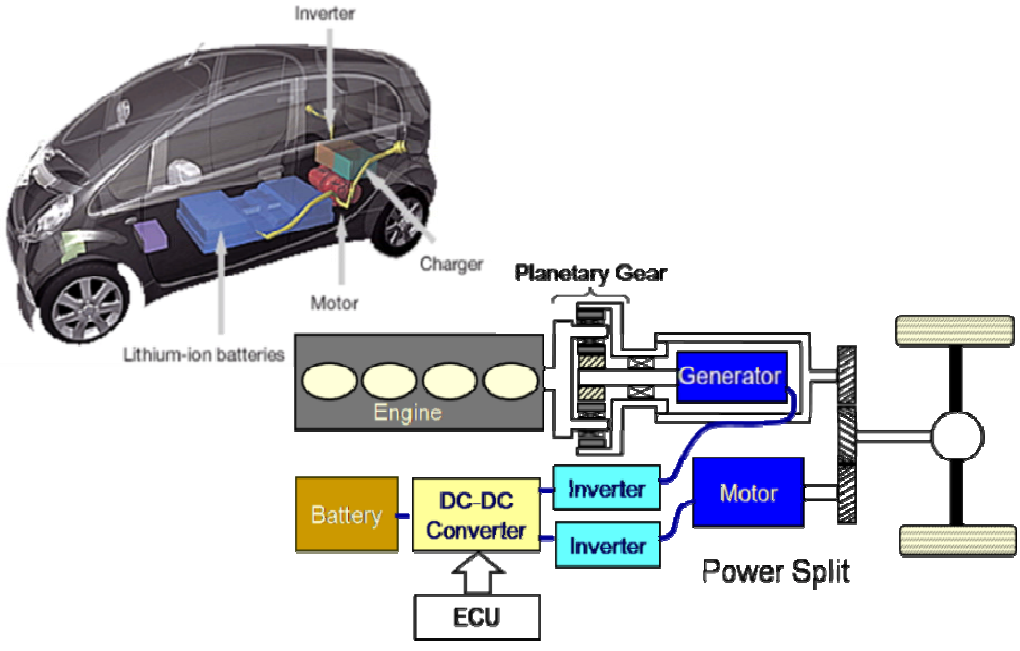
Source: Electric Drive Transportation Association

[1] Electric Drive Transportation Association definition http://www.electricdirve.org

Structure of the electric vehicle

An electric vehicle consists of an electric power train, charger, PCU/ECU[2], chassis, and battery module. The electric power train module generates power by converting electricity energy into dynamic energy. This module does not need breakthrough technology innovation because we are already using higher-level technology in ships. The other modules, except a battery also could be developed in almost industrialized country. Only optimization of its function in specific environments and mass production technology would be needed.

Figure 1. Plug-in hybrid electric vehicle structure



Source - Mitsubishi, KTEP

[2] PCU : **P**owerTrain **C**ontrol **U**nit, ECU : **E**ngine **C**ontrol **U**nit

The key technical enabler for all HEVs, PHEVs, and EVs is high energy, cost effective, long lasting and abuse tolerant batteries[3]. The battery accounts for roughly 75% of the incremental cost of achieving full HEV, PHEV, or EV capability. The battery power is responsible for storing and providing electricity for the motor energy, so battery power capacity (energy density) determines the durability of motor vehicles[4]. Although nearly all HEVs and PHEVs are currently powered by nickel metal hydride(NiMH), there is no doubt that lithium ion (Li+) battery technology will ultimately dominate the market. Lithium is non-toxic, light, high energy, has other desirable properties, and is still cheap and available.

Table 2. Li ion battery and NiMH battery performance comparison

	NiMH	Li ion	
		Status quo	Long-term
Capacity	70-80 wh/kg	150-180 wh/kg	beyond 200 wh/kg
Cost	$700/kwh	$900/kwh	Expected to reach $300/kwh
Life expectancy	500-700	800-1000	Beyond 1500
*Memory effect	Serious	Very low	Almost zero
Performance	General	Higher operating voltage and current characteristics better than NiMH	
Safety	Good	Poor	will be greatly improved
Pollution	Some	Some	pollution is very low
Tech. requirement	Normal	Slightly higher than NiMH	Expected to be improved
The degree of resource-rich	Normal	better	

* Source - SINOLINK （国金证券研究所）

[3] Deutsche Bank, "Electric Cars : Plugged In", pp21

[4] SINOKINK SECURITIES(国金证券) "新能源汽车行业研究专题报告"，pp7

Market trend

Electric vehicles appear destined for much more growth than is currently widely expected. The EIA's[5] 2007 Annual Energy Review estimates the actual number of BEVs on the road in 2004 as 49,536 and the preliminary estimated number for 2006 is 53,526. As well, in the summer of 2008 the NHTSA[6] estimated that HEVs could rise to 20% of the U.S. market by 2015 from just 2% of the market in 2007. In Europe, Roland Berger and J.D Power estimated that the market for electric vehicles could rise to 50% by 2015 from 2% in 2007.

Due to these prospects, most auto-makers around the world have already launched electric vehicles or plan to launch them in the near future.

Table 3. Major PHEV products on the market

Maker	Model	Time to Market	Battery	
			*Dist.	type
Fisker (U.S)	Karma	2008	80 km	Li +
比亚迪 (China)	F3DM, F6DM	2008	100 km	Li +
Tesla (U.S)	Whitestar	2009	+80 Km	Li +
GM (U.S)	Volt	2010	60 Km	Li +
Volkswagen (German)	Golf Twin	2010	50 Km	Li +
Chrysler (U.S)	Sprinter	after2010	35 Km	Li +/ NiMH
Ford (U.S)	Edge Hyseries	after2010	40 Km	Li + / NiMH
Toyota (Japan)	Prius PHEV	2011	unknown	Li +

Source：国金证券研究所（SINOLINK）

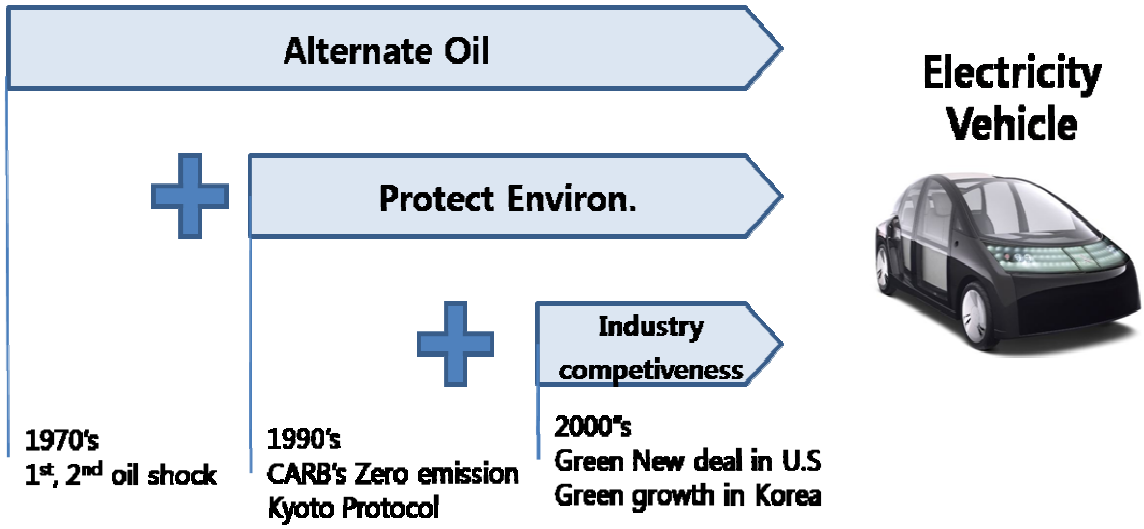
[5] **E**nergy **I**nformation **A**dministrative in the United States

[6] **N**ational **H**ighway **T**raffic **S**afety **A**dministration in the United States

Chapter 3. Electric Vehicles' Benefits

Recently, electric vehicles have come into the spotlight due to their many advantages. First, electric vehicles could save oil consumption. An electric vehicle converts oil usage into electric power, and promotes total energy system' efficiency. Second, electric vehicles could save the Earth. They reduce greenhouse gas emissions, and enhance the quality of the atmosphere. Third, electric vehicles are the future of the auto industry. Without a comparative electric vehicle, an auto-maker could not win the global competition. In addition, electric vehicle could use renewable energy (e.g., solar power) easily, and contribute to electric grid safety and efficiency. Thus, we can easily see that electric vehicles will be indispensable in the 21st century. We also know that global competition regarding electric vehicles has started.

Figure 2. Why an electric vehicle?



A. Energy perspective

The International Energy Agency in "World Energy Outlook 2008" estimated that world oil production will reach 104mb/d[7] in 2030, requiring an additional 64mb/d of gross capacity. This is six times the current capacity of Saudi Arabia.[8]

In addition, people cannot give up their current quality of life, which oil brings to us. Thus, we have to use another energy source instead of oil. Some countries, such as China and United States, use much more coal. Other countries such as Korea, use much more nuclear energy. All country will develop renewable energy, although it may not be a significant magnitude.

Table 4. 2006 world energy production

	Coal & Peat	Crude Oil	Gas	Nu-clear	Hydro.	Geoth, solar, etc	Combust. Renew.	Total
Prod.	3,076,946	4,029,638	2,439,128	728,415	261,137	66,249	1,184,359	11,795,752
Ratio	26.1	34.2	20.7	6.2	2.2	0.6	10.0	100

* Source - IEA Statistics, unit – KTOE (thousand tonnes of oil equivalent , %)

However a substitute for oil should be convenient to use like gasoline and diesel. Thus, the substitute should be converted electricity or hydrogen and be stored and transported. Some people said that in the future hydrogen will be using as major energy storage and transportation medium. But

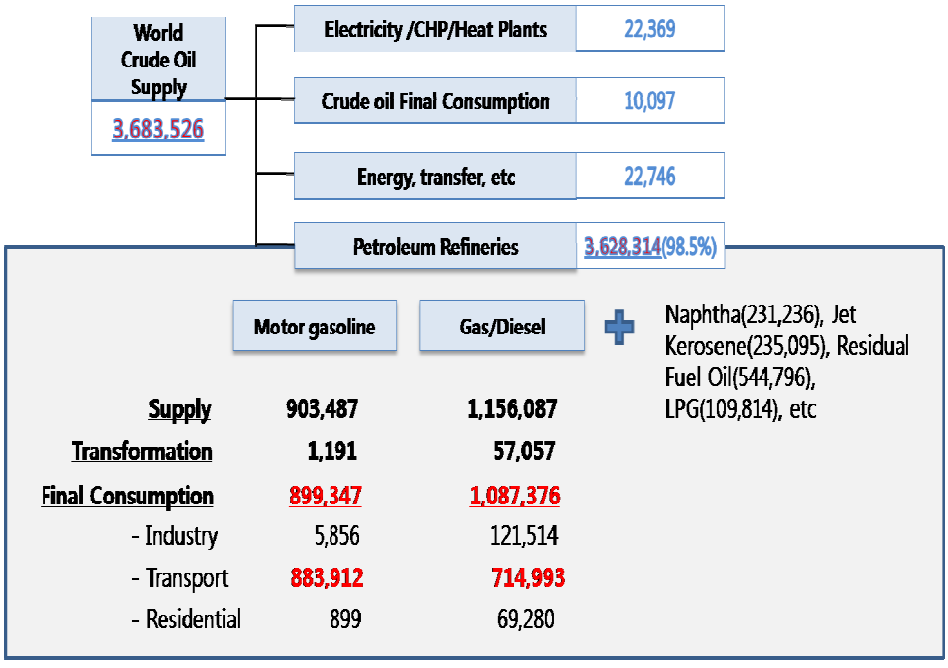
[7] Mb/d : million barrel per day

[8] Joseph A, Stainslaw, "Power Play(pp. 6)", Deloitte

electricity will be likely to continue to play a important role as energy transportation medium, as novel prize scholar said *"hydrogen is a way of storing energy and moving it from here to there. Unfortunately, it does not do either of these tasks very well. For these tasks, electricity is a much better answer. Electricity transmission is a superb way to move energy from one place to another place, and at least on a small scale, electrical power can be stored."*[9]

As shown in Figure 3, we can see that about 70% of oil is using in transportation such as sedan, bus, train and airplane. Thus, increasing of electric vehicle is major ways to substitute oil consumption.

Figure 3. World oil consumption in 2006



Reference - IEA Energy Statics

[9] Richard E. Smalley, "Future Global Prosperity : The Terawatt Challenge", 2005.7

This is because all types of EV use less oil or nothing. The efficiency of EV can be increased by three mechanisms;

- Shutting down the engine to idle when stationary, or at low speeds
- Recovering energy for future use through regenerative braking; and
- Downsizing the combustion engine, and operating at optimal efficiency.

In addition, PHEV and BEV use electricity as partial or full power source. Thus, oil could be substituted by electricity. Although electricity is generated by fossil fuels, gasoline and diesel are not used for power generation in most countries,

Electric vehicles could enhance net energy systems' efficiency. An electric vehicle's total energy consumption is lower than the usual inter combustion vehicles'. Even though oil refining is more efficient than a coal burning electricity plant, the net energy system efficiency in motors is much higher. If we consider a gas electric plant or a nuclear power plant, the gap between two systems will be much bigger.

Table 5. The net system efficiency comparison

		ICV	**BEV(I)**	**BEV(II)**
Fuel	Process	Crude oil → Motor gasoline	Coal → electricity	LNG → electricity
	Eff.(A)	83 %	35 %	42 %
Power Train	Source	Combustion Engine	Rotary motor	Rotary motor
	Eff.(B)	20 %	92 %	92 %
Total Eff.(=A * B)		17 %	24 %	29 %

Source-; World Wide Fund for Nature (alternating)

B. Environmental perspective

In cities across the globe, the vehicle is the single greatest polluter, as emissions from a billion vehicles on the road add up to a planet-wide problem. By IEA's report on greenhouse effects, world emits 20.8% of CO_2 in transportation, and especially vehicle emits 17.8% of total emission[10].

With a significant deployment of electric vehicle, CO_2 emissions and other pollutants could be greatly reduced. According to the EPRI[11] and the NDRC, electric vehicles are the key to reducing greenhouse gases and solving cities' atmosphere pollution.[12]

Table 6. Annual GHG emission reduction from PHEV in the year 2050

2005 Annual GHG Reduction (million metric tons)		Electric Sector CO_2 Intensity		
		High	Medium	Low
PHEV fleet Penetration	Low	163	177	193
	Medium	394	468	478
	High	474	517	612

Source : Environmental Assessment of PHEV(I), 2007. 8

* United States GHG emission in 2005 : 5817 million metric tons.

This also shows that PHEVs result in small but significant improvements in ambient air quality and reduction in deposition of various pollutants such as acids, nutrients and mercury. However, the primary emissions of

[10] United State Environment Programme ; http://www.unep.org/climatechange/

[11] EPRI : **E**lectric **P**ower **R**esearch **I**nstitute in US, NDRC : **N**atural **R**esources **D**efense **C**ouncil

[12] Environmental Assessment of Plug-In Hybrid Electric Vehicles(2007)

particulate matter (PM) increase by 10% with the use of PHEVs due primarily to the large increase in coal generation assumed in the study.

C. Industry perspective

Koreans calls vehicles "the flower of mechanics". Chinese call the auto industry "the pillar industry". This is because vehicles require vast range of technology, including diverse companies. Thus, many are employed in that field. This is why auto industry has a significant position in a state's economy. And we can understand why the United States tries to supports its automotive companies in spite of the great risks in the current recession. However, the rise of electric vehicles has caused auto industry paradigm shifts. As the core part in vehicles has changed from the internal-combustion-engine to the electric battery, the production method will change dramatically.

The production method will be similar to that for the personal computer. Especially the battery supplier role will become more and more important, and competition in the battery system (NIMH, Li Ion) will be severe. On the other hand, some suppliers (i.e. alternator, starter) have to prepare for market shrinkage. This could be an opportunity for Korea. Korea could make use of battery technology that is obtained from an IT industry such as cellular phones.

Chapter 4. What Electric Vehicle Mean to China

A. Energy perspective

China has huge fossil energy resources. In 2006, China's coal reserves were 1,035 billion tons, third in the world. In addition, Oil Shale[13] and coalbed methane[14] are relatively large volume of potential reserves. And, China has relatively abundant renewable energy resources.

Table 7. China's energy production and consumption

Country	World	China	United States
Energy Product (MTOE)	11,796	1,749 (14.8%)	1,654 (14.0%)
Net Imports (MTOE)	-	161	730
[15]TPES (MTOE)	11740	1,897 (16.2%)	2,320 (19.8%)
Population (million)	6,536	1,319 (20.2%)	299.8 (4.6%)
GDP (billion $, in 2000)	37,759	2,315 (6.1%)	11,265 (29.8%)

Source : IEA, Key World Energy Statistics 2008(criteria for 2006), modified

In addition, China's energy consumption is the second in the world after the United States. Since 20% of the world's population consumes 16.2% of worldwide energy, China's consumption level could be said to be below the

[13] Oil Shale is an organic-rich fine-grained sedimentary rock. It contains significant amounts of kerogen from which technology can extract liquid hydrocarbons.

[14] Coalbed methane is a form of natural **gas** extracted from **coal** beds. In recent decades it has become an important source of energy in United States, Canada, etc.

[15] TPES : Total Primary Energy Supply

world energy consumption average. However, when per-capita energy consumption is considered, China is still inefficient in using energy.

Notably, China's energy consumption is growing rapidly with the country's size. By 2010, China will overtake the U.S. as the world's largest energy consumer. In 2005, the U.S. used 35% more energy than China. In the past two years, 70% of the growth in demand for oil, and 80% in demand growth for coal, came from China and India, respectively[16].

One of the characteristics of China's energy consumption is higher reliance on coal. And 50% of the coal consumption is used for power development. In recent years, hydroelectric, nuclear and wind energy has improved to a significant percentage.

Table 8. China energy consumption ratio (unit - %)

Year	Coal	Oil	Natural Gas	Hydro power, Nuclear, Wind Power
1980	69.4	23.8	3.0	3.8
1990	74.2	19.0	2.0	4.8
2000	72.0	18.1	2.8	7.2
2002	72.3	16.6	3.0	8.1
2005	76.4	12.6	3.3	7.7

Source - China Statistics Agency,「 中國統計年鑑 2006」

China has reduced oil usage percentage from total energy consumption, but the oil usage amount has significantly increased. Accordingly, a significant amount of oil is imported from abroad. China started to be a

[16] Deloitte, "Power Play" pp11

net oil importing country in 1993. Until now, the net oil import scale exceeded 180 million tons. China's dependence on imported oil has dramatically risen, and came to 49.8% in 2007.

To improve China's immediate energy problem, electric vehicles are the key. The biggest obstacle for the energy self-sufficiency policy goal could be resolved by remarkable introduction of electric vehicles. As shown in Figure 9, half of the crude oil used to produce gasoline and diesel, and 63.4 % of gasoline and diesel consumption are used in transportation. If, however, 30% of all vehicles in China by 2030 were electric vehicle, China could save up to 700 million barrels of oil, or 10% of the estimated 6.2 billion barrels of oil the country is projected to need by then[17].

B. Environmental perspective

China has strong economic growth over the last 20–25 years, but it has had positive impact on the environment. Alongside economic growth, *technology improvements* over this period have created much-improved resource utilization. Energy efficiency has improved drastically—almost three times better utilization of energy resources in 2002 compared to 1978.

As a result of the *changing industrial structure*, the application of cleaner

[17] Paul Gao, Arthur Wang, August Wu, McKinsey and Company, "China Charges up : The electric Vehicle Opportunity", October 2008, pp6

and more energy-efficient technologies, and pollution control efforts, ambient concentrations of particulate matter (PM) and sulfur dioxide (SO_2) in cities have gradually decreased over the last 25 years. Implementation of *environmental pollution control policies*—particularly command-and-control[18] measures, but also economic and voluntarily measures—have contributed substantially to leveling off or even reducing pollution loads, particularly in certain targeted industrial sectors. At the same time, new environmental challenges have been created. Following a period of stagnation in energy use during the late 1990s, total energy consumption in China increased 70% between 2000 and 2005. Moreover, between 2000 and 2005, air pollution emissions remained constant or, in some instances, increased. The assessment at the end of the tenth five-year plan (2001–05) recently concluded that China's emissions of SO_2 and soot were 42 % and 11 % higher, respectively, than the target set at the beginning of the plan. China is now the largest source of SO_2 emissions in the world.[19]

The major causes of air pollution in China are thermal power plants and vehicle emissions. Therefore, developing clean fossil fuel power generation and minimizing vehicle emissions are the essence of the Chinese government's environmental policy. First, almost 100% of dust in coal

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[18] Command and control policy refers to environmental policy that relies on regulation (permission, prohibition, standard setting and enforcement) as opposed to financial incentives, that is, economic instruments of cost internalization.

[19] World Bank, February 2007, "The cost of pollution in 2007", pp1

combustion facilities was removed by 2006, so the total emissions of smoke and dust in 2006 are similar levels in 1980. And desulfurization facilities have expanded from 2% in 2000 to 30% in 2006. Second, China has established vehicle exhaust emissions standards, so vehicles that do not meet the standard are strictly prohibited to sale or import. In particular, clean-fuel-using vehicles are strongly supported. Given these circumstances, the electric vehicle is the center of solution to environment pollution.

C. Industry perspective

China's auto (including passenger cars and commercial vehicle) production has become the world's third largest. According to the OCIA[20], China produced 8,882,456 vehicles in 2008, which is the third place in the world after Japan (11,596,327) and the United States (10,780,720).

Table 9. Auto production statistics

Country	Cars	Commercial Vehicle	Total	Growth Change (%)
Japan	9,944,637	1,651,690	11,596,327	1.0 %
United States	3,924,268	6,856,451	10,780,720	-4.5 %
China	6,381,116	2,501,340	8,882,456	22 %
Germany	5,709,139	504,321	6,213,460	6.8 %
South Korea	3,723,482	362,826	4,086,308	6.4 %

Source : OICA Web[21]

[20] Organisation Internationale des Constructeurs d'Automobiles ; The International Organization of Motor Vehicle Manufacturers

[21] http://oica.net/category/production-statistics/

At present, there are 19 auto-makers in China. Including small and medium auto makers, the number of auto makers comes to 130. Toyota, GM and all of the world's major auto-makers have established joint-venture companies in China and they have been producing vehicles. The size of the Chinese auto sales market is also growing day by day. In 2008, 9,380,000 vehicles, including 5,040,000 passenger cars, were sold. This is the second highest total in the world. According to some media[22], China's monthly vehicle sales surpassed those in the United States for the first time in January 2009, moving this country closer to becoming the world's biggest auto market. Chinese vehicle sales also have cooled, but hardly as dramatically. China's best-selling auto-makers are GM and Germany's Volkswagen AG, but the country's own ambitious producers, such as Chery Automobile Co., are growing fast.

As well, the sales growth potential is enormous. CAAM[23] says that China's vehicle registration number is fifth in the world, but it is the early stages of adoption because only 33% of the population has car. In some research,[24] China's vehicle stock will increase nearly twenty-fold, to 390 million in 2030.

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[22] http://www.usatoday.com/money/autos/2009-02-10-china-auto-sales_N.htm

[23] China Association of Automobile Manufacturers

[24] Joyce Dargay, Dermot Gately and Martin Sommer, January 2007, "Vehicle Ownership and Income Growth, Worldwide: 1960-2030"

Table 10. Projection of Income and Vehicle Ownership, 2002-2030

Country	Per-capita income (thousands, 1995$ PPP)			Vehicles per 1000 Population			Total Vehicles (millions)			Ratio of growth rates Veh. Own. to Per-cap. income
	2002	2030	Annual Growth Rate	2002	2030	Annual Growth Rate	2002	2030	Annual Growth Rate	
China	4.3	16.0	4.8%	16	269	10.6%	20.5	390	11.1%	2.20
India	2.3	7.3	3.4	17	110	7.0	17.4	156	8.1%	1.98
U.S.	31.9	56.6	2.1%	812	849	0.2%	234	314	1.1%	0.08
Japan	23.9	42.1	2.0%	599	716	0.6%	76.3	86.6	0.5%	0.31
Korea	15.1	39.0	3.5%	293	609	2.6%	13.9	30.5	2.8%	0.77

China has made a big increase in quantity, but is relatively unsatisfied with the development in quality. The Chinese government has set up local auto –makers' market ratio goals, but it turns out that the goal could be impossible to meet in the near future. As well, in terms of technology, there are also gaps from developed countries. Therefore, China should look for a jump strategy under the auto industry's paradigm shift, rather than secure a competitive advantage in the ICV auto industry.

To some extent, China is making a virtue of a liability. It is behind the United States, Japan and other countries when it comes to making gas-powered vehicles, but by skipping the current technology, China hopes to get a jump on the next. [25]

[25] "China Vies to Be World's Leader in Electric Cars", http://www.nytimes.com/2009/04/02/business/global/02electric.html

Chapter 5. China's efforts

A. Chinese government' policy[26]

As previously investigated, China has a strong motive to adopt electric vehicles. Electric vehicles represent China's chance to significantly reduce oil dependency, improve environment status and to become global leader in the auto industry.

The Chinese government has already taken a number of substantive actions to develop and deploy electric vehicles. The Ministry of Science and Technology is actively encouraging the development of alternative engine technologies. The Ministry has mandated that 10 % of China's vehicles must run on alternative fuels by 2012. To support this ambitious goal, the ministry has launched the "863 plan", an initiative to funnel money into research and development of EV technology. The ministry also recently announced a plan to roll out 10,000 hybrid electric and fuel-cell vehicle in 10 cities. In addition to funding, the ministry could also facilitate the development of electric vehicle technology by implementing industry-wide standards that govern the technical specifications of electric vehicles. Such standards would lower the technical entry barriers and costs to companies and academic institutions investing in electric vehicle research.

Tax incentives can encourage consumers to purchase more fuel-efficient

[26] Paul Gao, Arthur Wang, August Wu, McKinsey and Company, "China Charges up - The Electric Vehicle Opportunity", October 2008, pp11

vehicles. On September 1, 2008, a "green" tax went into effect that is aimed at encouraging consumers to switche to smaller, cheaper, and more fuel-efficient vehicles. Taxes on vehicles with engine capacities over 3 liters were increased to 40%, whereas taxes on the smallest vehicles, with engines under 1 liter, were reduced to 1%.

The government can also accelerate the introduction of the long-delayed fuel tax, which will not only help make electric vehicles more economically than ICE vehicles in China, but also help shift government spending from subsidizing oil and gas companies to providing incentives to companies and research instituties that develop alternative power train technologies.

And throgugh collaboration with power companies and automakers, the government can facilitate the roll-out of recharging stations. For example, Better Place and Renault-Nissan are partnering with the governments of Israel and Denmark to deploy an electric vehicle recharging grid by 2011 that wil be powered by solar and wind energy, respectively.

According to a recent news report,[27] Chinese leaders have adopted a plan aimed at turning the country into one of the leading producers of hybrid and all-electric vehicles within three years, and making it the world leader in electric cars and buses after that. The goal, which radiates from the very top of the Chinese government, suggests that Detroit's Big Three, already struggling to stay alive, will face even stiffer foreign competition on the

[27] http://www.nytimes.com/2009/04/02/business/global/02electric.html

next field of automotive technology than they do today.

Subsidies of up to $8,800 are being offered to taxi fleets and local government agencies in 13 Chinese cities for each hybrid or all-electric vehicle the organizations purchase. The state electricity grid has been ordered to set up EV charging stations in Beijing, Shanghai and Tianjin.

B. Chinese auto maker trends[28]

In addition to foreign auto-makers, almost all auto-makers are developing various types of electric vehicles. Especially, local auto-makers used the Beijing Olympics to promote EVs with Chinese government support.

Table11. China major auto maker trends in electric vehicle

Auto-maker	Electric vehicle trends
SAIC Group (上汽集团)	- Emphasis on mild HEV[29] by its own development - Buick Regal eco-hybrid released on market - As well, hybrid buses and fuel cell vehicle in progress
FAW Group (一汽集团)	- Emphasis on full hybrid electric vehicle[30] - Hybrid sedan/bus have been produced on a small scale - In 2009, hybrid sedan will be released, now selling Prius

[28] SINOKINK SECURITIES(国金证券) "新能源汽车行业研究专题报告", pp24

[29] **Micro hybrid:** Micro hybrid systems stop the engine only while idling (while still running heat, A/C, etc.), and instantly start it when the vehicle is required to move, providing efficiency gains in the 5%-10% range.

Mild hybrid: Mild hybrids stop the engine while the vehicle is idling and provide additional power during vehicle acceleration, providing fuel efficiency gains in the 10%-20% range.

[30] **Full hybrid:** Full hybrids provide enough power for limited levels of autonomous driving at slow speeds, and they offer efficiency gains ranging from 25% to 40%.

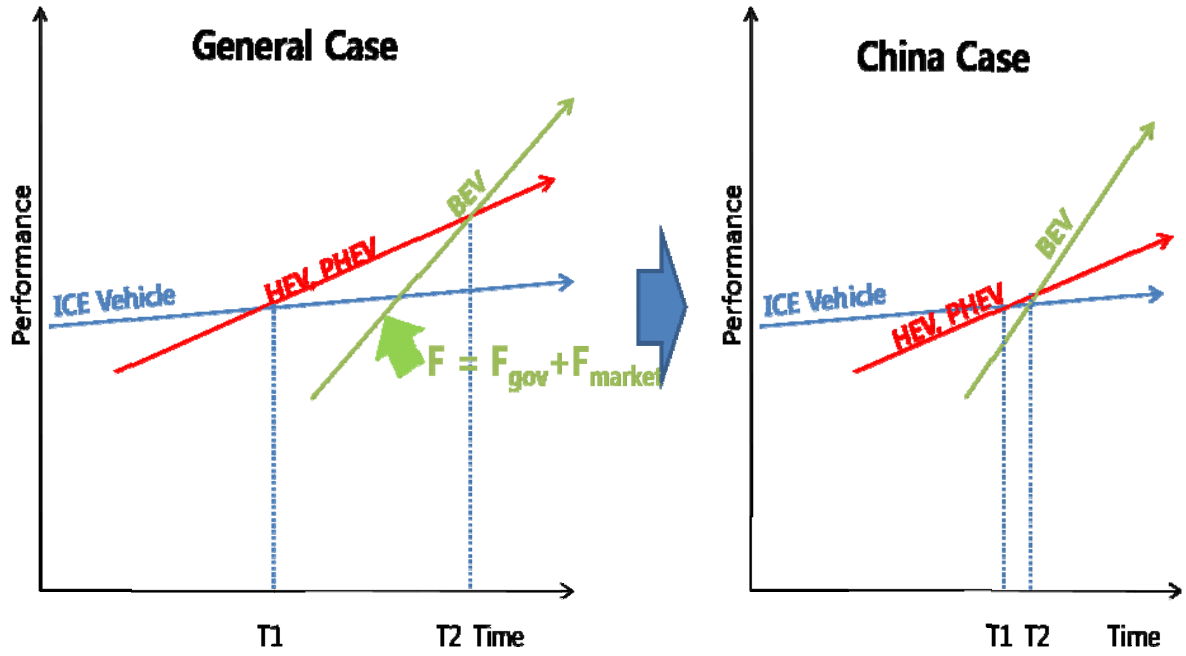
	- BEV and ethanol fuel vehicle in R&D progress
Dongfeng Motor (东风汽车)	- Mainly developing sedan HEV - 2007.11 the first mass production for domestic sedan - Has certain technology in BEV - During the Olympics, demonstrated 415 HEV to run
Beiqi Group (北汽集团)	- Emphasis on Hybrid bus; already hundreds of buses operating in Beijing and Guangzhou. - 2008.8 production Futian, the second-phase hybrid bus - Cooperation with Tsinghua(清华) Uni. in fuel cell bus
Chang'an Automobile (长安汽车)	- Focus on mild hybrid development, Jie Xun("杰勋") HEV participate in Beijing Olympics pilot project - The 2nd half of 2009, Zhi-xiang HEV will be released - 2008, Cooperation with Canadian Green ELECTROVAYA, battery maker, to develop electric cars
Canton Steam Group (广汽集团)	- For hybrid electric vehicle and hydrogen fuel cell vehicle and its autonomous power system development
Chery Automobile (奇瑞汽车)	- Development in the core technology in hybrid electric vehicles and commercialization - 2007. 7 Production Chery A5 BSG (Micro hybrid). And put in Wuhu taxi market, the lowest cost of their vehicles only to upgrade 5,000 - 2007.10 Release higher levels Chery A5 ISG (mild hybrid) - BEV and fuel cell vehicle R&D in progress
Geely Automobile (吉利汽车)	- Vigorous research in HEV (Micro and Mild) under the national 863 projects - Set up 5-year plan to develop 5 types of hybrid vehicles ; the plan put into operation by the end of 2009 - BEV and fuel cell vehicle R&D in progress
BYD Automobile (比亚迪汽车)	- BEV and HEV development based on battery technology - 2008.12 F6DM and F3DM released by using dual-mode (DM) technology - 2008, Launched BEV with original BYD "ET-POWER" iron batteries (lithium iron phosphate batteries) , carrying iron battery life up to 300km

VI. Electric Vehicles' Prospects in China

1. In China, directly jump into BEV

In China, the auto market could directly jump into BEVs bypassing the HEV and PHEV periods. It is expected that it will be difficult for BEVs to enter the mass market for the time being because battery technology has not yet fully matured. But in China, there are favorable conditions for BEVs compared with HEVs and PHEVs. BEVs could be promoted, developed, and deployed earlier. Figure 4 shows that proactive government support and favorable market condition accelerate BEV performance enhancement.

Figure 4. BEV leap-up mechanism



Below are the reasons that BEVs are favorable in China.

a. A BEV is a more desirable model than HEVs and PHEVs.

   If a BEV has a considerable driving range, the BEV is superior to the HEV and the PHEV. This reduces oil consumption so the BEV is more useful for solving China's dependence on overseas oil. The BEV also improves certain environmental qualities, such as the atmosphere and noise levels.

b. The BEV corresponds to the Chinese auto industry's interest.

   With HEVs and PHEVs, local Chinese auto-maker is inevitably inferior to foreign auto-makers (e.g., Toyota, Honda), because local auto-makers have less technology on ICE compared with foreign auto-makers. But a BEV depends completely on a motor and battery. With the BEV, Chinese auto-makers have the opportunity to prepare at the same starting point.

c. The Chinese government has the capability to support BEV mass production.

   China has a huge economy, so just deploying BEVs in public areas (public transportation, post office, etc) is enough for auto-makers to set up mass production facilities.

d. Chinese have similar experiences with charging transportation vehicles.

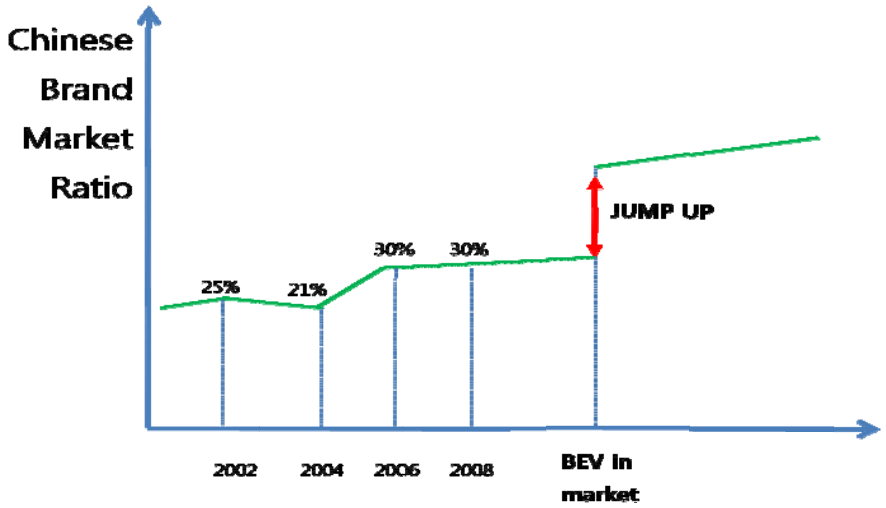
   Electric two-wheelers (E2Ws) are gaining widespread acceptance in

China ; this is arguably the most successful electric-drive market in the world. If the E2W's success continues, it may accelerate the development of batteries and larger electric vehicles.[31]

2. Chinese local auto maker will jump up

When the BEV prevails in the Chinese vehicle market, local Chinese auto - makers have a high probability of good results. With the support of the Chinese government, local Chinese auto-makers have slowly increased their market share. But during the introduction period of BEVs, Chinese auto-makers' sales ratio could jump, because Chinese auto-maker have strengths and favorable business conditions concerning BEVs.

Figure 5. Local Chinese auto-makers' prospects in terms of the market ratio



[31] Jonathan Weinert, Joan Ogden, Dan Sperling, Andrew Burke, "The future of electric two-wheelers and electric vehicles in China", pp1

a. BEV is just the initial state

Local Chinese auto-makers have the same chance as global auto-makers. As BYD president Wang Chuanfu said in an interview with Xinhua News; "The traditional vehicle (ICU) has been developed for 100 years, so there is very small space for technology innovation. While new energy vehicle (EV) has just started, and there is much room for innovation. China's battery technology is not backward, and the future of electric vehicles should be dominated by China."

b. BEV has a simple structure

A recent *Wall Street Journal*[32] article described how assembling electric vehicles is relatively simple. "Electric cars use only basic motors and gearboxes, and have relatively few parts," the article notes. "Aside from perfecting the battery itself, they're far easier and cheaper to build -- and that makes for a level playing field."

c. Local auto-makers have an advantage in marketing

Local Chinese auto-makers could appeal to Chinese citizens' pride in their country. By purchasing domestic BEVs, Chinese citizens could consider the purchase as creating a symbolic commodity that stands for their people's success in industrialization and modernization similar to the American airplane in 20th or the British train in the 18th century.

[32] http://online.wsj.com/article/SB123172034731572313.html

d. Foreign auto- makers' strength will be offset in BEV.

A BEV is simple, and the technology differences with local auto-makers will not big, so it would be very hard for foreign auto-makers to maintain their superiority in safety and quality. For example, Samsung was an inferior brand in CVT TV but now has become a high-value brand due to paradigm shift.

3. The BEV industry model will be similar to cellular phone

Considering BEV' characteristics, the BEV's industry supply chain model will be similar to the cellular phone industry rather than personal computers. The biggest difference between the two industries is who leads to create more value. In the cellular phone industry, manufacturers design products and then, decide on the components. On the other hand, PC manufacturers buy parts and components that suppliers have designed for various manufactures' use.

Table 12. Key difference between the PC and cellular phone industries

Commodities	Personal Computer	Cellular phone
Design	Normal	Very important
Representative Company in industry	Supplier (CPU : Intel)	Manufacture (Nokia, Samsung)
Regulation	small	Relatively big (safety, frequency)

For generations, manufacturers such as Toyota and General Motors were the profit leaders in the automotive industry. As the importance of battery in the auto industry became critical, some experts predicted that a broad shift in value from manufacturers to suppliers will occur.

I predict otherwise, for the following reasons.

A. There are many suppliers that can produce EV components.
   - Even though the battery determines the EV's performance, EV manufacturing can have a chance to choose a supplier from global companies; Toyota, Panasonic, JCS, Hitachi, AESC, Sanyo. GS Yusa, A123 System, LG Chem, Samsung, SK Corp, Toshiba & Enerdel, etc.
   - When GE selected LG Chem's battery as the company's EV in December 2008, there was a very strong competition among suppliers.

B. The style will be more important in EV
   - According to motor expert, Prof. Lee in Hanyang University, the driving performance among EV would not be much like ICV. because high-power motor technology is similar among industrialized countries.

     So, similar to the cellular phone market, consumers would choose their vehicle based on style and brand power.

Chapter 7. Conclusion

Electric vehicles have many advantages

Electric vehicles replace oil consumption with other energy sources, and reduce the total energy consumption. In addition, EVs could improve the atmosphere environment and reduce greenhouse gases. As well, EVs will determine the 21st-century landscape of the auto industry because electric vehicles are the most promising and plausible technology model.

Electric vehicles are crucial to China

China has a high dependence on overseas oil resources. Moreover the absolute demand for oil resources is huge so China must secure oil imports by various diplomatic tools.

In addition, China has been improving the environment, and obtained a certain level of performance. However, additional improvement is necessary, because many Chinese suffer from pollution.

In industry aspects, China is trying to use the EV transition period to become global leader in the auto industry. For a long time, China has invested to catch up with developed countries in internal combustion engine vehicles. But China has failed to meet its expectations, although China is the world's second largest auto production market.

How electric vehicle will develop in China

a. In China, the auto market could directly jump into BEVs bypassing the HEV and PHEV periods. In China, there are favorable conditions around BEVs compared with HEVs and PHEVs. BEVs could be promoted, developed, and deployed earlier.
b. As BEV prevails in the Chinese vehicle market, local Chinese auto-makers will increase their sales share. Over the last few decades local Chinese auto-makers have slowly increased their market share.
c. The BEV's industry supply chain model will be similar to cellular phone industry rather than the personal computer. Although the battery supplier's role will be stronger, manufacture will still play a core role in the auto industry.

Policy Recommendation for the Korean Government

a. The Korean government should concentrate on EV, especially BEV as a future vehicle model
   - Considering the technology development trend and Korean environment, EV is a realizable solution among alternative vehicles.
     ▪ A Fuel cell vehicle has limitations in commercialization because the core components' membrane is too expensive, and production and distribution of hydrogen are hard to develop economically.

▪ Biodiesel and ethanol vehicles also have high costs, because the raw materials are not abundant in Korea. So, these could not be solutions for the Korea in the future.

- Investing in a specific vehicle model could be risky, but the Korean government has to concentrate its resources to promote a promising area.

▪ Even though Korean companies such as Samsung have limited resources and relatively low-level technology infra, the companies have succeeded in the semiconductor and cellular phone market by resolute investment.

▪ There should be a transition period (HEV, PHEV) in the automotive industry, but the final winner will be the one that has a competitive BEV model.

b. Promote at full-size pilot project add on the present public R&D support and tax reduction

- China has designated the first batch of 13 cities for the pilot project of trial-running more than 60,000 electric vehicles in public transportation, public services and postal service[33]
- Similar to China, Korea also has to start the EV deployment project. But Korea should be concentrate on BEV to maximize outcome. For

[33] http://autonews.gasgoo.com/auto-news/1009857/China-may-launch-EV-support-policy-this-month.html

example, the government should designate a specific area (Jesu Island) and construct an electric power system for BEV such as a charging system. The government should also choose a BEV manufacturer and support its sales by deduction taxes and giving subsidies. The BEV manufacturer does not need to be a Korean auto-maker. But, the government similar to China government could request the manufacturer to use a Korean company's battery, motor, etc.

c. Find a BEV cooperation area with China

- Hundreds of global companies tried to create relationships with Chinese auto companies because of China's infinite domestic market. So Korea has to present an attractive cooperation project.
- For example, the BEV will be important network node similar to cellular phone in the future, so the BEV will bring about various business models. Based on Korea's advanced IT infrastructure, we could cooperate with setting up a common platform for BEV network.

Future Research Agenda

According to the theory of 'disruptive innovation framework' by Professor Christensen at Harvard Business School, the strategy that improves innovative product/technology with inferior performance in

a preexisting market is likely to fail. Thus, innovative product has to explore new market.

This means that electric vehicle also have to develop a new market rather than act as substitute for ICV right now. The market opportunity lies in the development of undeveloped customer demand. Therefore, my next research will focus what kinds of business will prosper in the future. To foster this movement, what should be done in public areas?

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