2010

Electric Vehicles: Market Opportunities in China

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SUBMITTED TO

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FOR

SENIOR THESIS

FALL 2010

TABLE OF CONTENTS

CHAPTER ONE

EXCITING OPPORTUNITIES FOR AN ELECTRIC VEHICLE MARKET IN CHINA

Hype surrounding Electric Vehicles (EVs) is quickly gathering momentum on a worldwide stage. While EVs were once thought of as eccentric science projects or trendy options for die-hard environmentalists, redesigned models are now making their way into the mainstream. Actors across the board are starting to take notice; automobile manufacturers are scrambling to get in the game by developing new prototypes and launching models in select markets, governments are beginning to consider policies to encourage EV adoption within their jurisdictions, and consumers are starting to consider trading in their traditional internal combustion engine models in favor of EVs.

The momentum behind the EV market has been rapidly building over just the past year, and it is unclear how long and at what level of intensity this will carry on; will EVs come to dominate the worldwide transportation fleet, or will they only be one class of vehicles in the mix? It is also uncertain as to which international markets EVs will successfully penetrate. There is enormous potential for EVs in a number of regions around the world, with the United States and Europe certain to be two very important markets. However, this paper will narrow the international perspective and focus attention solely on the emerging EV market in China.

The Chinese market for EVs is distinct from Western markets chiefly because of the sheer room for growth. The United States today has 0.765 vehicles per capita; contrast this figure to China's 0.128 vehicles per capita (Hanlon 2010). China already has an enormous vehicle fleet, but this figure illustrates the staggering potential for growth in the volume of automobiles within the nation as an increasing number of Chinese achieve middle-class spending status. Considering the projected increase in new car purchasers, the opportunity for the automobile industry – and specifically the EV industry – are extremely promising and exciting. On the flip side, this projected growth also represents the potential for enormous environmental costs; in a country which already suffers from extreme air pollution and which emits a staggering amount of carbon dioxide, a surge in cars on the road will have hugely detrimental consequences for both the regional and global environment. These growth projections illustrate that if there is a single nation for which widespread EV uptake will make a considerable impact, it is China.

The potential for EV adoption in China is made even more relevant by the fact that the Chinese government is already generating considerable momentum behind both EV manufacturing and EV consumption. Ultimately, the Chinese have a great advantage over the United States and other Western nations in developing the EV market at a rapid pace due to the government's ability to impose mandates and policies in a top down fashion to achieve their goals. With China's highest ranking government members already eager to embrace the EV market, the near term success of the new market looks promising; as an example of his interest in EVs, Premier Wen Jiabao recently appointed Wan Gang – chief scientist for the Chinese government's research panel on EVs – as the Minster of Science and Technology (Bradsher 2009). This appointment is a symbolic representation of the support behind EVs on the central government level; subsequent chapters will highlight more substantial government policies designed to encourage domestic EV manufacturing and consumption.

One purpose of this paper is to provide a snapshot as to where the EV market currently stands in China, in terms of both progress in domestic EV production and in initiatives paving the path for EV consumption. There are already several established Chinese automobile manufacturers who have entered the EV space, all of which have experiences to draw upon in the discussion of how future operations can be improved. On the consumer side, there are a number of noteworthy government initiatives and private industry plans that can help us chart how the market for EVs in China may evolve. Looking at current conditions of the market is only so useful however because of the rapid pace with which the EV industry is evolving; thus, the main goal of this paper will be to look at the inconsistencies and gaps in both the supply-side and the demand-side of the EV market to suggest ways in which private industry or government can approach these challenges to facilitate the creation of a more robust market.

In looking at the shaping of the EV market in China, this paper will also address the set of benefits conferred by the stimulation of the manufacturing and consumption of EVs. Analyzing these benefits is important to understanding the government's current and continued push to deploy EVs; this motivation has been the driving force behind current progress and will continue to serve as the foundation of the industry. The three benefits that will be explored in subsequent chapters include: the economic benefit of developing a robust domestic manufacturing base for EVs, the environmental benefits of reduced emissions locally and reduced contributions to global warming, and the security benefits of reducing demand for foreign oil. Subsequently, this paper will map out how policies and agendas can be channeled such that the manufacturing and consumption sides of the EV market rise to meet the challenge of achieving these benefits.

CHAPTER TWO

DOMESTIC ELECTRIC VEHICLE MANUFACTURING: BENEFITS AND PROGRESS

The benefits of manufacturing EVs domestically

No one would contest China's impressive industrial power and its rapidly expanding economic influence. The country has enormous capital and labor resources that both industry and the government are itching to employ to spur the continued development of the country. In this effort to continue building its industrial clout, assuming a leading role in the development and manufacturing of EVs could be a strategic move for China. The clean-tech industry as a whole promises enormous potential for China, as it would allow Chinese leaders to reconcile their desire for growth of the country's GDP with the call for sustainable development and responsible environmental stewardship. EVs in particular offer a great opportunity for China to explore innovative advances in its automobile industry, which over the last decade has established itself as a pillar industry in the Chinese economy (Farhoomand *et al.* 2010). Despite the industry's importance in the domestic economy, Chinese automobile manufacturers still have a long way to go before they can compete on technology, quality, reputation, and profitability with American, European, and Japanese rivals. Taking on a pioneering position in the EV industry represents an opportunity to elevate Chinese firms' prominence and competitive edge in the world market for automobiles, while providing additional stimulus to the Chinese economy.

For the Chinese government seeking to encourage both economic growth and responsible environmental policy, developing an EV industry that can compete and excel in the international market is a laudable goal. The international market potential for EVs is rapidly increasing – JP Morgan estimates that by 2020, 11 million EVs will be sold worldwide, thereby representing 13 percent of the global passenger market (Brown *et al.* 2010) – and China will want to capitalize on this opportunity. Historically, Chinese auto-manufactures have not established strong markets outside of China, but they are increasingly on the lookout to do so; Chinese auto-manufacturer SAIC is rapidly growing its market share in India by recently purchasing a 50 percent share of General Motors in the country (Hanlon 2010). Chinese automobile manufacturers may be able to realize their goals of large-scale international expansion if they are given the chance to sell massive quantities of their products domestically, allowing them to build their product strengths and systematically cut costs, afterwards leveraging this towards global expansion (Friedman 2008).

The appearance of this vast opening in the international market is due to the hesitation on the part of American, Japanese, and European automakers to substantively employ electric technology in their vehicles. In recent months, announcements about the release of new EVs and PHEVs such as the Chevy Volt and the Nissan Leaf have surfaced, along with the promise of upcoming EV models by BMW and other manufacturers. Despite these recent stirrings, the market leader in the EV segment is still very much un-established. With this relatively flat playing field, Chinese auto manufacturers are all well positioned to establish international market share if they get a foothold early on.

Although establishing a strong position in the international EV market is the ultimate goal, Chinese auto manufacturers are looking at their domestic market as more than just a testing-ground for their products. As will be examined in more detail in later chapters, the Chinese market for EVs is poised to take off, and as such it will be extremely lucrative for Chinese companies to capture the local consumer market early before foreign firms have the chance to firmly establish market share in the country. Although there are a huge number of factors that will determine Chinese consumer uptake of domestically-manufactured vehicles, Chinese automobile companies are at an advantage by holding a large portion of the domestic market for standard vehicles; as of 2008, domestic products accounted for more than 95 percent of vehicle sales in China (Gallagher 2006). As the domestic manufacturing potential continues to grow and expand into the EV segment, Chinese EV manufacturers will have an advantage from tapping into the Chinese market early on.

Developing EV technology and manufacturing capacity at home is thus a laudable strategy for sustainably developing China's economy; furthermore, it is a strategy that will widely benefit many national interests. The national government benefits by utilizing a national EV industry to prop up China's image as an economic powerhouse and technological leader. Big business and industry benefit from the profits they can make at home and abroad by establishing leadership in a burgeoning industry. Finally, Chinese citizens benefit from a robust domestic EV industry because of the jobs that it can generate. Recognizing the strategic significance of a domestic EV industry, the next step is to analyze the current potential of Chinese EV manufacturing companies and to consider various measures by which their outlook for market ascension could be improved.

The path to manufacturing EVs domestically

Current developments

In considering the potential and the future for the Chinese EV manufacturing industry, it is useful to take stock of the current developments. There are several Chinese auto manufacturers making inroads into the EV space; the most notable of these include: SAIC Motor, Coda, BYD Co., Chery Automobile, Brilliance Auto, Chang'an Automobile Group, Geely Automotive, and Lifan Group (Liu & Kanellos 2010). Growing momentum behind the electric segment was displayed at the 2009 Shanghai Auto Expo, and at last spring's Beijing Auto Expo the trend continued, with manufacturers unveiling ninety-five distinct electric models (Dumaine 2010). Several manufacturers displayed extravagant concept cars such as SAIC Motor's *Yez*, which utilizes an EV engine but actually has a negative carbon footprint due to the addition of solar panels and other gadgets on the car body (Hanlon 2010). In a more marketable vein, many popular Chinese manufacturers are launching various PHEV and pure EV models, all with variations of style, range, battery type, and price. Many of these manufacturers are also partnering with foreign car companies to better position their products both domestically and internationally. Coda in particular is already looking beyond the Chinese market, setting its sights on the U.S. market with plans to sell its pure EV model to American consumers by the end of this year (Liu & Kanellos 2010). The following chart summarizes some of the recent developments in the Chinese EV and PHEV market, citing each manufacturer's various model offerings and some of their features as have been indicated by industry news articles and manufacturers' websites.

Table 1. The following summarizes China's chief EV manufacturers and their current vehicle models.

Automobile Manufacturer	***Company Partnership***	***Vehicle Model***	***Release Date***	***Expected Price***	***Range***
SAIC Motor	GM	**E1** – pure EV **Roewe 550** – PHEV	Both scheduled to release in 2012		85 mi
Coda		Pure EV	Scheduled release 2011	US$37,400	120 mi
BYD Co.	DaimlerChrysler	**E6** – pure EV **F2DM** - PHEV	Both are already in use in the Shenzhen taxi fleet	US$37,700 US$24,800	205 mi 68 mi
Chery Automobile		**S18** – pure EV **QQEV** – pure EV **M1EV** – pure EV	Released February 2009 Released February 2009 Exhibited Beijing Auto Show 2010	US$19,200	93 mi 50 mi 50 mi
Brilliance Auto	BMW	**Zhonghua EV** – pure EV	Scheduled release 2011		90 mi
Chang'an Automobile	Ford	Pure EV model	Scheduled release July 2011		
Geely Automotive		**EK1** – pure EV **EK2** – pure EV **EC7** - PHEV	Scheduled release 2011		50 mi 110 mi 40 mi
Lifan Group	Chinese Academy of Sciences	**Lifan 320** – pure EV **Lifan 620** – pure EV	Released at 2010 Beijing Auto Show		125 mi 125 mi
Beijing Automotive Holding		**BE701** – pure EV	Released November 2010		124 mi

(Liu & Kanellos 2010; Dumaine 2010; Hanlon 2010; Rowley & Inoue 2010)

Beyond this snapshot of recent product developments, it is useful to look at how Chinese EV manufacturers compare to foreign competitors in terms of key factors such as technology, costs of production, and marketability of their products. By examining these challenges in adopting EV models faced by China's most promising auto manufacturers, we can analyze how these companies may better position themselves for prominence in the EV market. The next step is to try to better understand how government policy may play a role in aiding and abetting some of these concerns about the viability of Chinese firms in the EV market.

Technology: The Chinese Advantage

China has long lagged behind foreign car manufacturers in internal-combustion engine (ICE) technology, but the Chinese see EVs as an opportunity to 'leapfrog' established automobile technology and become the dominant global manufacturer in this new product industry (Dumaine 2010). In terms of EV technology, Chinese companies enjoy an advantage compared to their foreign counterparts due to their substantial expertise in the batteries that power EVs (Burgelman & Grove 2010). The lithium-ion battery that powers an EV is the integral element to developing an efficient, reliable, and quality car; for this reason, much of the discussion surrounding the efficacy of various EV models revolves around the battery. China has a long track record of producing lithium-ion batteries, and thus Chinese firms are slated to enjoy certain competitive benefits when it comes to generating quality battery technology that can be employed in EVs.

BYD is the most significant Chinese player in the market for rechargeable lithium-ion batteries. In recent years the company has grown its business units in automobiles and their complementing batteries, while reducing its divisions in batteries for cell-phones and other electronic devices. BYD's output of rechargeable EV batteries reached 1875 million units in 2009, up 82 percent from the previous year (RIC 2010). Manufacturing capacity for rechargeable lithium-ion battery technology is only widely established in China, Japan and South Korea, thus Chinese EV manufacturers will enjoy advantages over American and European competitors when it comes to integrating battery technology into their models. Some analysts claim this technological advantage will translate into significant performance gains; Scott Laprise, an auto analyst from CLSA Asia-Pacific Markets, argues that "the Chevy Volt has no chance [competing with BYD's new F3DM]" (Liu & Kanellos 2010) based solely on BYD's battery expertise.

The prominence of BYD in the global lithium-ion rechargeable battery market is a marked advantage for Chinese EV developers, but it also draws attention to the need for the Chinese to get a handle on the various technological shortcomings that plague these rechargeable batteries. The three most cited concerns about battery technology include durability, safety, and cost. While cost can be reduced somewhat by technological improvements, breakthroughs in battery technology will be most helpful in delivering performance in terms of durability and safety (Karplus *et al.* 2009). In terms of durability, the battery is the most important and the most unreliable part of the EV. Vehicle manufacturers are currently aiming to develop guarantees on the batteries for five-years or 100,000 kilometers of driving distance (Nishino 2010), but at present the potential for the longevity of EV batteries are very much still in question.

Safety is perhaps an even greater concern associated with battery technology. Although lithium-ion batteries are the most effective types of batteries to employ in EVs, they are also much more vulnerable to short-circuiting and overcharging. Short-circuiting occurs more frequently in lithium-ion batteries because higher electricity flows lead to higher temperature increases; the temperature can increase to several hundred degrees within seconds, thereby heating up neighboring cells which can result in the combustion of the entire battery (Jacoby 2007). Overcharging becomes a severe problem because it can change the chemical structure of the anode and the cathode, which in the worst case scenario leads to the battery exploding or catching fire (Lowe *et al.* 2010). Current technologies reduce the chance of overcharging by employing very precise voltage control systems on each battery pack set, however, further safety measures need to be developed to instill confidence in the EV industry and the batteries that drive it (Lowe *et al.* 2010).

These durability and safety concerns are particularly relevant to Chinese EV manufacturers who are on the forefront of developing the technologies to reduce the incidence of these battery-related problems. The interface between battery manufacturing companies and local EV manufacturing companies has the potential to be very high. In the case of BYD, the company is integrating its business operations to utilize its rechargeable battery products in the manufacturing of its very own EVs. This close relationship can help drive innovation in the EV market as a whole, and increase Chinese EV manufacturer competitiveness on the world stage.

Batteries are of course only one element in the context of an entire EV. Although China has an advantage in battery technology, the nation is still behind the US and Japan in current vehicle technology on the whole (Bradsher 2009). The Chinese automobile industry on its own is young and un-established compared with foreign automobile companies, thus the Chinese in many respects will be playing catch up. Foreign engineers are superior to Chinese engineers in terms of designing sophisticated battery-control systems and integrating these into the cars (Dumaine 2010). Chinese automobile companies have historically underinvested in R&D efforts relative to foreign competitors; while R&D staff made up around 30 percent of the total automobile industry workforce in developed countries during 2006, this figure was 8 percent in China (Farhoomand *et al.* 2010). To be competitive in the global EV market, Chinese auto manufacturers will need to invest in R&D and match well established foreign auto technology to make the features in their EVs just as functional and reliable as in those included in their foreign-made competitors'.

In addition to furthering EV technology through industry cooperation, the government can also play a role in catalyzing large improvements in this area. Already the government is "placing their bets on the EV segment" by injecting much-needed R&D funding into the industry (Liu & Kanellos 2010). In addition to funding for the development of EV-specific technologies, in 2009 the Chinese government invested ten billion RMB (US$1.46 billion) in a program to help Chinese automotive innovation catch up to foreign car standards (Bradsher 2009). The government can help the industry's competitiveness and long term viability by continuing to provide it with capital for R&D. Because of a relatively high degree of consolidation in the industry for EV batteries and EVs, the government should avoid picking the winners early on by doling out significant funding only to selected groups or companies. The money would be best channeled through the robust network of Chinese universities and research organizations, which can aid in the development of the technology and then filter it down to the Chinese car manufacturers. Dispensing R&D funds through these established pathways is the quickest and most effective strategy for encouraging the technological preeminence of the Chinese EV manufacturing industry.

Cost of Production: Does China have an edge in the EV market?

The widespread thinking about products made in China is that they are significantly cheaper than goods produced in Western countries; this commonly held wisdom may not actually hold true in the EV sector. Simply looking at prices for the EVs slated to hit the market this year, we see that BYD's model is estimated to cost US$ 40,000, which is substantially more expensive than the US$32,800 (pre-tax incentives) consumers will pay for the Nissan Leaf (Liu & Kanellos 2010). It is still early days for EV manufacturing in China, so there is ample opportunity for Chinese firms to bring their cost curves down rapidly as they gain more expertise in the industry. Several elements to consider that will factor into the cost breakdown of Chinese EVs include: labor costs, modes of production, material costs, and government stimulus.

Labor costs are the hallmark of China's low cost exporting dominance in consumer products across the board. In the EV manufacturing industry, these will undoubtedly also be a key advantage of driving prices down. Despite the integral role that labor plays, analysts must be careful not to overstate its importance, because low labor costs have a slightly diminished importance in a highly capital intensive and innovation driven industry such as what we find in the EV industry.

In the realm of EVs, vertical integration of the auto manufacturing companies could be a significant factor in driving down costs. This notion is based on recent successes that Chinese solar module manufacturers have experienced as a result of the vertical integration of their companies (CIR 2010). Aligning the manufacturing and final assembly of all the pieces in the product through vertical integration can lead to significant efficiency gains and resultant cost reductions (Mahoney 1992). There is ample room to achieve vertical integration in the Chinese EV industry due to the presence of many automobile part manufacturers and cutting edge battery manufacturers. In the case of integrating battery manufacturing into the EV manufacturing firm, cost savings come with omitting the need to transport batteries great distances, because their considerable weight makes them extremely expensive to ship (Lowe *et al.* 2010). Altogether, coordination in material shipping, simplifications in negotiations between suppliers and buyers, and increased opportunities for holistic innovation will lead to significant cost reductions for Chinese auto manufacturers who can vertically integrate.

In yet another parallel to the Chinese solar market, Chinese EV manufacturers may enjoy cost competitiveness due to their ability to ramp up production to extremely high volumes. The cost of the lithium-ion battery that charges the EV is hugely inhibitive for many EV manufacturers. Fortunately, prices are falling quickly; in 2007 batteries cost US$1,000 per kWh, whereas now they cost only US$400 per kWh (Kanellos 2010). Despite this positive trend, it is unclear how long the price decline will continue, as Moore's law will probably cease to apply as the technology becomes increasingly more mature. Additional price drops will instead be dependent on ramped up manufacturing volumes which will allow for economies of scale (Kanellos 2010). Chinese manufacturers will be capable of creating massive economies of scale due to their massive manufacturing capacity, which in turn will drive battery costs lower than their foreign competitors.

Chinese auto manufacturers are also positioned to receive significant advantages in material prices that will in turn drive down the price of their EVs. Batteries – again, the most costly element of the EV – require rare earth metals which are subject to somewhat volatile world market prices. Up to 97 percent of these rare earth metals are produced in China, thus supply shortages are not such a serious concern for China as they are for the U.S. and other foreign EV manufacturers (Service 2010). China is also poised to manipulate the world market for rare earth elements at its whim, which could be very harmful to foreign firms. The Chinese government has already started to tighten its grip on their supply; in July 2010 China announced it would cut exports of rare earth elements by 40 percent, simultaneously applying export tariffs of 10 to 25 percent of their value (Service 2010). Depending on how the Chinese government chooses to wield its control over world rare earth element supplies, Chinese EV producers could have a very large margin of cost advantage over their foreign competitors.

The final ingredient that could figure into large cost advantages for Chinese EV manufacturers is the support the government chooses to give to the industry directly. In the renewable energy arena, the government has mandated that state-owned banks grant loans to renewable energy companies at extremely low interest rates (CIR 2010). This *de facto* subsidy to the solar industry has allowed it to be extremely competitive with established companies in Germany and other European countries. By extending this policy to EV manufacturers, the government would be providing the burgeoning industry with cheap capital to give it the start it needs to develop and gain momentum. After compounding the cost advantages discussed earlier with this added government support, the Chinese EV industry is well positioned to compete in the international market on price.

Marketability of Chinese Manufactured EVs

In considerations of technology and cost, Chinese EV manufacturers are in a positive position to garner advantages relative to foreign competitors; it is in the marketability aspect that Chinese companies face the greatest hurdles. Two main obstacles stand in the way of Chinese EV appeal, namely, credibility of performance and the consumer perception of these Chinese models. These concerns will also have varying ramifications for how well the Chinese cars will be adopted at home and how well they will be adopted abroad.

The EV battery once again comes into play as the most prominent credibility concern associated with the vehicle. As has been previously discussed, lithium-ion batteries in general have a poor reputation for reliability, but Chinese battery makers in particular have a bad reputation for quality control. Incidents have arisen in the past with Chinese-manufactured lithium-ion batteries used in cell phones, and have drawn a considerable amount of bad press (Bradsher 2009). Quality control within Chinese battery manufacturers thus becomes paramount to facilitating the acceptance of Chinese EV models; Sujeet Kumar of the battery company Envia Systems has commented that all major international car makers have opted for Japanese, Korean, or American lithium-ion batteries due to this severe lack of oversight in regards to reliability of Chinese manufactured batteries (Liu & Kanellos 2010). For Chinese EV manufacturers purchasing lithium-ion batteries from Chinese battery companies, or else integrating the battery manufacturing into their own operations, improving the quality and reliability of the product, and subsequently the public perception, is key to ensuring market demand for their products.

In addition to revamping their manufacturing processes to ensure that quality control standards are employed, there are several other steps Chinese manufacturers of lithium-ion batteries and EVs can take to turn around these negative perceptions of their products. Part of this process will depend on the degree of coordination between battery makers and the EV manufacturers that purchase them; companies will have to decide at which point in the value chain warranty will be assumed for the battery. For vertically integrated firms this answer will be explicit, but for those firms that are not, strong relationships will need to be formed between battery suppliers and the auto companies purchasing the batteries in order to negotiate a comprehensive approach to addressing liability for battery performance.

Chinese EV manufacturers may also choose to improve reputability and quality by partnering with U.S. car companies (Liu & Kanellos 2010). This is a real possibility, because in order for foreign car manufacturers to sell to the Chinese market, national laws require that these companies form joint ventures with Chinese companies (Dumaine 2010). It would be highly advantageous for Chinese firms to leverage these relationships with reputable, well known foreign firms to purport the viability and reliability of their own technology. This strategy has potential to be very effective in the short term to improve public perception, however, from a long term perspective Chinese firms have no choice but to effectually improve the quality of their products so as to live up to the expectations and demands of customers.

Government imposition of standardization benchmarks could also serve to increase confidence in Chinese produced EVs. The Chinese government could mandate these benchmarks itself, or else adopt international standards and make domestic companies adhere to them. The Society of Automotive Engineers International is the organization primarily focused on standards that relate to the auto industry, and is thus poised to begin the process of standardizing the EV sector (Brown *et al.* 2010). Should Chinese EV manufacturers embrace international standards, consumers both in China and around the world would have more faith in the domestically-produced cars measuring up to foreign competitors. Even after Chinese-made EVs have earned reputability in China, the road to acceptance in foreign countries is likely to be slower and more difficult; the imposition of an international standard for testing and product quality would substantially alleviate consumer concerns and may allow for Chinese EVs to successfully penetrate foreign markets.

Beyond the reputability of the products for quality and reliability, there is also a big question of whether Chinese-made cars of any variety can be marketed as fashionable and desirable to consumers both within and outside the country. Chinese cars have traditionally been thought of as 'low end' because historically they have served poorer markets; they are not viewed as luxury goods at home or abroad. This presents a difficulty for the EV industry, because at least at the onset, their models will be more expensive than traditional internal combustion engine cars. Chinese companies will thus have to angle their product differently to appeal to a higher-end clientele, or else market their EVs as cheaper alternatives to competing foreign EVs. There may be a place for some Chinese firms to adopt both of these strategies, but ultimately if an EV manufacturer wants to grab the growing market share of wealthier clients, they will have to change the image of their products. This goal may be an uphill battle; it is widely accepted that in China, “status is the most important thing when buying a car,” and as a result Japanese, Korean, and Western brands generally hold more appeal to the Chinese consumer (Dumaine 2010).

Getting beyond just the public perception towards Chinese EVs, there are ample improvements to be made to the appeal of the cars. It is a fairly commonly held notion that Chinese cars in general are not considered visually appealing; Coda’s cars have been criticized as being “basically ugly” by well-know automobile commentators (Liu & Kanellos 2010). In order to ramp up the appeal and to create a more glamorous image that will speak to a wider, wealthier consumer base, Chinese car manufacturers need to seriously rethink their body and interior designs.

Considering technological advantages, cost of production, and marketability as some of the chief elements determining the success of selling Chinese-made EVs domestically and abroad, it appears that there is good chance of Chinese ascension within the world marketplace. The Chinese auto industry’s relative youth means that there are still ample pathways for improvement as Chinese companies streamline their overall structures and functions, as well as their intelligence in the industry generally. Further advantages may spring out of the industry-wide embrace of EV technology, thereby increasing national competition which will drive innovation and improvement. Provided that the Chinese government continues to view building a domestic manufacturing base for EVs as strategically important to the nation, government stimulus and help to the industry can play an integral role in cementing its success.

CHAPTER THREE

BENEFITS OF CHINESE CONSUMER UPTAKE

The previous chapter highlighted the positive benefits for stimulating the domestic economy through the development of a strong EV manufacturing industry. This chapter seeks to explore two of the other societal benefits of EVs, namely, the environmental impacts and the energy security benefits of transitioning to a predominantly EV fleet. While the last chapter focused on the supplier side of the EV market, this chapter looks at benefits associated with the market demand for EVs; subsequent chapters will thus examine how these positive benefits can be capitalized on by stimulating a robust domestic consumer base.

Assessing the Environmental Benefits of EVs for China

EVs have long been touted for their merits as environmentally responsible alternatives to traditional internal combustion engines. Eliminating the use of petroleum in a large proportion of the national vehicle fleet could have significant benefits for China's local environment and for its commitments to international climate change negotiations. The goal of this section is to un-wrap these two issues more fully in order to examine the benefits conferred by EVs in these areas. Beyond this, the section will examine in more depth the actual potential for environmental benefits from EV deployment. Based on these analyses, we can speculate as to whether it is in China's interest to facilitate the widespread adoption of EVs for the purpose of improving environmental conditions.

Air pollution: what role do vehicle emissions play?

Compounded with a series of other polluting practices, runaway air pollution levels in China's urban areas have created an environmental crisis in the country. This well-documented problem has implications for the quality of life in China's cities, and more pressingly, for the physical health of the country's population. A study by a Chinese research institute found that air pollution was linked to 400,000 premature deaths every year in the country (Li 2006). Health effects from air pollutants are wide ranging, including a number of respiratory and pulmonary diseases afflicting people of all ages. China's air pollution frequently exceeds healthy levels; more than eighty percent of Chinese cities have sulfur dioxide or nitrogen dioxide emissions above what the World Health Organization has defined as healthy thresholds (Li 2006). Current air pollution trends in China are likely to be unsustainable if the nation's leaders desire the continued growth and prosperity of their people. In the effort to reduce these unhealthy emissions to a safe level, the nation will need to consider changes to many of its operating industries, including transportation.

Although the air pollution problem in China cannot be narrowly attributed to vehicle emissions – emissions from coal-fired power plants and other industrial processes also play a large role – the transportation sector does represent a significant segment that needs to be addressed. Petroleum fueled vehicles emit numerous pollutants that harm human health, including carbon monoxide, nitrogen oxides, sulfur dioxides, hydrocarbons, particulate matter, and other hazardous air pollutants. In the year 2000, up to seventy percent of the carbon monoxide emissions in Beijing and Shanghai could be attributed to motor vehicles (Lee 2006). With vehicle numbers and usage increasing, particularly in urban centers, there is enormous pressure on authorities to outline a solution for maintaining healthy emissions levels. The Beijing Statistical Bureau estimates that the vehicle population in Beijing been increasing at an average annual rate of 14.4 percent since 1990 (BSB 2003); if these growth rates continue, and possibly even increase into the future, urban centers will be faced with huge loads of vehicle-caused air pollution that will adversely impact the wellbeing of the areas' inhabitants.

EV proliferation is by no means a zero-emissions proposition; as the next section will discuss, the emissions profile of the energy used to power these vehicles will have considerable implications as to how environmentally beneficial they really are. However, in the context of discussing air pollution concentrated in urban areas, EVs indisputably offer a large degree of emissions relief. Even for an EV powered exclusively by electricity from coal-burning power plants, there is a limited local impact because the power plants generally are not centrally located, and thus the emissions caused by burning the coal are not contributing to heightened local emissions. Obviously, the optimal situation would be to limit the emission of air pollutants across the entire nation, but in the shorter term, it would be in China's best interest to de-escalate emission levels in concentrated, urban centers; this can be achieved by integrating a large number of EVs into the nation's transportation fleet. As growth in China's urban centers continues at a rapid pace, the health of the people in these cities will depend on lowering *local* emissions, and EV use can offset some of these (Weinert 2008).

Statistical and visual proof point unambiguously to China's severe problem with air pollution; the nation has no choice but to begin seriously confronting this issue immediately. In considering the transportation sector alone, EVs offer a viable option for eliminating many of the emissions derived from this segment. Purely from the standpoint of the health impacts caused by vehicular emissions, widespread adoption of EVs has notable merits for China. Consumer uptake of EVs would have tangible positive effects for China's people, particularly residents living in urban centers, and also for China's national image, which has faced international criticism in the past for its poor air quality, as was showcased by the 2008 Beijing Olympics.

Mitigating climate change

The International Energy Agency has estimated that the transportation sector accounts for twenty percent of all greenhouse gas emissions worldwide (IEA 2006). Generally speaking, emissions from the transportation sector are extremely difficult to mitigate and to integrate into carbon accounting schemes. For coal-burning power plants and other stationary sources, devices can be installed to capture carbon dioxide emissions, which can later be stored underground. Although Carbon Capture and Storage practices have yet to be deployed in any substantial way, the technology exists and could make an impact for stationary emissions sources in the future. The transportation sector by contrast, is much more difficult to control, with so many small, mobile emissions sources, which ultimately contribute a large volume of carbon emissions as a whole. By changing over to a fleet largely composed of EVs, it may be much easier to simultaneously contain and reduce greenhouse gas emission levels from the transportation sector.

Global climate change caused by greenhouse gas emissions is clearly a formidable issue in need of concerted mitigation efforts across multiple international jurisdictions; the question remains, how much mitigation effort is China willing to employ? China's actions at Copenhagen and other international forums negotiating and addressing mitigation actions on climate change suggest that the country's leaders have only a conditional interest in the issue. Their prevailing attitude is one of apathy, provided that mitigating carbon dioxide emissions means slowing down the nation's industrial growth in a substantial way. Be that as it may, mounting international pressure may indeed elicit some action on the part of the Chinese to encourage more responsible growth that will not exacerbate forces contributing to climate change. Although in the short term, climate change mitigation may not be the primary argument in favor of promoting local adoption of EVs, this is nonetheless a distinct benefit that can be promoted. This leads us to further investigate how significantly carbon dioxide emissions could actually be reduced by facilitating a widespread shift to EVs in China. Whether climate change mitigation becomes a principal argument in favor of EV deployment, or not, it will be important to analyze the energy mix used to power EVs, in order to fully understand the implications for China of such a change in the vehicle fleet.

Ultimately, the climate change impact of an EV will depend on where the vehicle is charged, and what energy source mix is powering the grid at that location. Due to the variance of energy mixes across the grid, it is impossible to determine with certainty what the emissions impact of an EV would be relative to an internal combustion engine. Many studies have been done attempting to determine what the disparity in emissions would be between these two vehicle models; the results of some of these studies are summarized in the table below:

Table 2. Estimated carbon dioxide emissions in grams per mile for different vehicle models, as estimated by three separate studies (Duvall & Knipping 2007; Parks *et al.* 2007; Kromer & Heywood 2007).

	Electric Power Research Institute (Duval & Knipping 2007)	**National Renewable Energy Laboratory (Parks *et al.* 2007)**	**MIT Sloan Automotive Laboratory (Kromer & Heywood 2007)**
Internal Combustion	450 g	410 g	477 g
Hybrid	295 g	299 g	140 g
PHEV20* – 2010 Coal	325 g	X	X
PHEV20* – 2035 Coal	305 g	X	X
PHEV20* - Renewables	150 g	X	X
PHEV20* – Off Peak	X	247 g	X
Electric Only	X	X	185 g

* PHEV20 refers to a Plug-in Hybrid Electric Vehicles with a twenty-mile all-electric range.

Despite small discrepancies between these different studies, what these data ultimately show is that the environmental efficacy of EVs and their PHEV relatives depends heavily upon where the electricity powering them was generated and when the charging occurred (Karplus *et al.* 2009). Based on the calculations from the above studies, EVs do confer environmental advantages over internal combustion engine vehicles even when charged on a coal-intensive grid, but ultimately the emissions savings will be greater if the grid is dominated by hydroelectric power, nuclear power, natural gas, or renewable energy sources (Brown *et al.* 2010). Additionally, emissions can be reduced by charging the vehicles at off peak times when renewable energy sources such as wind are dominating the grid.

The numbers provided in the previous study are specific to the United States, which generally has a cleaner energy mix than China. Thus in China, the value of EVs in reducing emissions is slightly less because China's grid is much more carbon-intensive than the U.S. grid (1 kg CO_2/kWh_{China} versus 0.58 g/kWh_{US}) due to high coal use (Weinert 2008). This implies that China could leverage even more environmental benefits from EV adoption by transitioning its energy mix away from coal, or by engaging in carbon sequestration activities that capture carbon dioxide emissions from coal-burning power plants and prevent them from escaping into the atmosphere.

EV batteries: the hidden environmental impacts

This section will briefly highlight a few of the issues associated with the rechargeable lithium-ion batteries used in EVs in order to get a general sense of some of the broader implications of switching to a largely electric fleet. A thorough examination of the lifecycle associated with lithium-ion, and other battery types used in EVs, does not reveal any glaringly detrimental environmental effects, but it is still important to consider potential issues that may arise in order to fully understand the implications of a widespread EV adoption.

The first consideration associated with a potentially widespread adoption of EVs is the boom in demand for lithium and rare earth elements used in batteries, which could put considerable strains on world supplies (Brown *et al.* 2010). With the large-scale production of EVs, increased mining for a limited supply of the necessary battery elements will increase adverse environmental impacts. Deposits of these materials have not been fully explored, and the extent of their availability is not yet known; it will be important to recycle these elements from used EV batteries as much as possible to ensure the most sustainable use of these limited resources (Brown *et al.* 2010).

The second concern associated with EV batteries is how to dispose of them at the end of their lifecycle. The average expected lifetime of a rechargeable lithium-ion battery is estimated to be about ten years (Brown *et al.* 2010). Although these types of batteries are not considered to be hazardous waste, if large volumes of them are frequently disposed of, this will need to be done responsibly. Again, this presents an optimal opportunity to employ concerted recycling efforts, thus minimizing the environmental impacts of disposing battery material, while simultaneously conserving resources.

Assessing the Energy Security Benefits Associated with EV Uptake in China

Another notable benefit of stimulating the widespread uptake of EVs within China's domestic vehicle fleet is the reduction of national dependence on petroleum. The transportation sector commands a considerable portion of China's demand for petroleum, and at present, most of it is highly reliant on petroleum as a fuel source; as of 1998, petroleum was the predominant fuel powering China's cars, minibuses, small trucks, and small vans, and it accounted for 88 percent of the total transport energy consumption (AMR 2002). The demand within the transport sector continues to grow at a rapid pace, which will put enormous strains on petroleum supplies at a magnitude that cannot yet be accurately predicted. The number of vehicles in China continues to expand – estimations of vehicles in use grew from 5.5 million in 1980, to 43.6 million vehicles in 2007 (Leung 2010). During this same time period, the petroleum demand in the transportation sector grew at an average annual rate of seven percent, from 25.2 million tons of oil equivalent in 1980 to 191.24 million tons of oil equivalent in 2007 (Wang 2009). Looking at this growth from the perspective of oil demand, these numbers elicit concern as to whether oil supply can keep pace accommodating the nation's needs. From the standpoint of energy security, it is necessary to also keep in mind other consumption uses for oil, including industry and agriculture. These sectors will serve to further contribute to the national demand for petroleum, putting a strain on the oil that can be used for transport; by 2030 the International Energy Agency predicts that Chinese oil demand will reach 808 million tons per year (IEA 2008).

The issue of energy security comes into play because of the uncertainty of petroleum supplies available to China. Domestic petroleum supplies have already effectively been exhausted given China's enormous demand; China became a net oil importer in 1993 (Hanson 2008). Currently, China imports about two-thirds of its oil and this proportion is continually rising (Dumaine 2010); China's net oil imports are forecasted to rise to 13.1 million barrels per day by 2030, up from 3.5 million barrels per day in 2006 (Hanson 2008). Thus, although domestic production continues to occur, increases in demand are far outstripping increases in Chinese production. China's measure of net import dependency has increased from 7.5 percent in 1993, to 50 percent in 2008, and with forecasted development, should continue to rise (Leung 2010). This severe domestic shortage of oil leaves China vulnerable to negotiating the international markets to obtain its petroleum, raising national concerns about energy security.

With such low domestic reserves of oil relative to its energy needs, China will inevitably become more and more reliant on international supplies. As a result of China's ever growing demand, world prices for oil will continue to be pushed higher. This will put considerable strain on the domestic economy; with gasoline priced at about US$4 a gallon, it is already an expensive commodity, especially in a country where the per capita income is only US$2,800 a year (Dumaine 2010). An increase in this price will put considerable stress on the average Chinese consumer, and on the nation as a whole. This direct impact on China's consumers has positive implications for potential EV adoption, because with continually rising prices at the gasoline pump, consumers will identify the budgetary benefits of investing in an alternatively-powered vehicle.

In addition to the ramifications for China's economic security, the nation's insatiable demand for oil will have implications for its political interactions. Currently, half of China's oil imports come from the Middle East, yet the extent of China's demand for oil has forced it to turn to new international markets with increased frequency (Hanson 2008). In 2009, the Chinese government signed deals with Russia, Kazakhstan, Brazil, Venezuela and Angola for oil (Cala 2009). China has also been pushing increasingly into Africa, and some experts suggest that China's need to secure natural resources is the driving force behind its calculated foreign policy investments in the continent (Hanson 2008).

Even given the current numbers, it is clear that China is heavily dependent on foreign oil, and that this reliance could give way to undesirable economic and political compromises. However, what is most concerning in this situation is the uncertainty of how much China will grow in the near future; conservative forecasts suggest that China is rapidly headed for an energy security crisis, but the reality could be far worse if population growth and vehicle use exceeds predictions.

Should China's growth in the transportation sector continue at such a fast pace, the nation will have a pressing interest in diversifying the energy mix powering its vehicle fleet. Although diesel and other fuels are one option to pursue, powering a large portion the transportation fleet by electricity may be a more sustainable option. Solely from the vantage point of energy security, China's coal reserves confer a considerable advantage in deploying an EV fleet; capitalizing on the vast reserves of this domestic commodity means that China will not have to worry about looking outside its borders to procure massive quantities of petroleum. China has only 6.1 percent of the world's oil supply per capita, but it has 79 percent of world's coal per capita (Ze-min 2008); these statistics illustrate the obvious disparity between these national reserves and signal that domestic availability of fuel sources should be taken into account.

From an energy security standpoint, it is thus advantageous for China to tap into its coal reserves to power the electricity grid, and thus its vehicle fleet. However, this strong focus on coal does have negative environmental implications that conflict with environmental considerations. Therefore, it may be prudent for Chinese leaders to look at coal as a short-term option for powering the grid and the transport sector, keeping in mind the long-term goal of increasingly substituting renewables into the energy mix. Proliferation of renewable energy in China will be a gradual process, but weaning off the national demand in the transport sector for oil can occur more quickly. Looking strictly at energy security, it makes sense for China to encourage the proliferation of a domestic EV market to eliminate certain vulnerabilities in economic or political situations that hinge on looking internationally to supply the country's petroleum needs.

CHAPTER FOUR

FACILITATING DOMESTIC UPTAKE OF ELECTRIC VEHICLES IN CHINA

Consumer choice and EVs

In order to advance the environmental and energy security benefits discussed in the previous chapter, and to provide a solid market for domestically produced EVs, the Chinese consumer base needs to be amenable to switching from the traditional gasoline powered car to an EV. Examining more closely the consumer perception of EVs, the two primary obstacles to uptake include a wariness to embrace EVs due to their unique and untraditional attributes, and the increased cost of an EV relative to a traditional car; the goal of this section is to more fully understand these two hurdles.

Marketing the EV

The nature of car use in China's urban centers naturally lends itself well to uptake of EVs on an individual basis. Commutes in urban areas are typically short and often at very low speeds due to the intensity of street traffic. As a result, the range issues associated with traditional EVs should not be an issue in most circumstances; even at the low threshold of miles per charge, most Chinese commutes will not be hindered by the need to engage in intermittent charging (Bradsher 2009). Another typical complaint about EV models is their lack of acceleration and speed – some models may peak at sixty miles per hour (Bradsher 2009). This limitation should not be hugely problematic for Chinese drivers either, due to the low speeds they travel at during their commutes, which typically take place in congested traffic.

Because EVs are rather well-fitted to Chinese commuter needs, it may be relatively easy to target first time Chinese car buyers. In 2009, four-fifths of the Chinese car market was made of up first-time car buyers (Bradsher 2009). First-time car owners will not already be accustomed to the greater power and longer range of gasoline fueled cars, thus they may be less likely to consider carefully these limitations. With the rapid ascension of China's middle class, a fresh segment on new car purchasers is quickly growing; this demographic change creates an enormous market potential for EVs to grow as a proportion of China's vehicle fleet.

The consumers who already own traditional internal combustion engine vehicles and are in the market for a new car are likely to be the more difficult segment of the population to target for EV uptake. Even if EV range and power is not a logistical concern for these drivers, they may not be quick to eagerly adopt an electrically powered model that operates so differently from what they are used to. The rate of uptake may depend largely on how EVs are marketed in China; will car companies push them on the premise of their environmental merits? Will they be presented as an economically smart alternative to traditional cars in the face of future gasoline prices? Or will car companies find a way to market them as a trendy and cutting edge product and thus appeal to a high-end clientele? It is still very much unclear which marketing strategy will reach the majority of the Chinese consumer base, but it is likely that the two most important messages will concern the economy of the EV, appealing to the frugal or else new middle-class consumer, and its high-end quality to appeal to the tendency of the Chinese to view cars as status symbols.

It is up to the EV manufacturers, whether they are domestic or foreign, to design and market the EV such that it carries appeal to Chinese consumers. If the Chinese government wants to facilitate domestic uptake, there is little it can do to influence public perceptions of EVs short of imposing heavy-handed mandates. In 1998, the Chinese government single-handedly facilitated the boom of the domestic electric scooter industry by banning the use of regular gasoline-powered scooters in many cities. As a result of this policy, annual sales of electric scooters grew from fifty-six thousand vehicles in 1998 to over twenty-one million in 2008 (Yang 2010). Although this example illustrates the potential for the government to facilitate such a rapid and complete market shift, this is not really a viable option for the automobile market. Automobiles are such a massively important commodity that the transition from internal combustion engine vehicles to EVs will need to occur more gradually and in a way that makes economic sense. The next section will discuss the options that the government has to exert its power over the market effectively – that is, influencing market prices.

Cost considerations and the EV

Ultimately, the cost of the EV model will be the overwhelming factor influencing its widespread uptake in the Chinese market. EVs are forecasted to be notably more expensive than gasoline-powered cars, and this price disparity is likely to continue into the foreseeable future. For one segment of consumers seeking luxury cars, this additional expense may not be a major issue, but for frugal Chinese consumers, and for new members of middle-class society purchasing a car for the first time, price will be an extremely important factor. Somehow, car companies must demonstrate that EVs have substantial economic value relative to traditional vehicles. In some cases, consumers will purchase EVs at a higher ticket price with the long-term outlook of saving money on gasoline in the future. For perhaps a majority of consumers, however, there will need to be a more immediate economic incentive to entice them to invest in an EV.

While targeting pure consumer preference through policy measures is nearly impossible, addressing the cost disparity between traditional vehicles and EVs can be done through targeted government subsidies and taxes. The most direct method of addressing EV cost would be for the government to grant a subsidy to consumers purchasing EVs. The Chinese government is already offering subsidies on EVs to certain consumer segments; the central government offers subsidies of RMB 50,000 (US$7,352) for hybrid cars and RMB 60,000 (US$8,824) for pure EVs to local authorities and transport companies (Kanellos 2010). This subsidy program could be distributed more widely to reach consumers purchasing vehicles for personal use, thereby bringing the prices paid by consumers on EVs down to meet the market prices of traditional cars, and encouraging wider EV uptake.

Subsidies are an attractive policy because they are relatively straightforward and easy to implement, however there is a series of drawbacks suggesting that widespread consumer subsidies for EVs may not be the most efficient or effective way to facilitate EV uptake. First, subsidizing the consumption of EVs may not be an equitable policy; subsidies on EVs may disproportionately benefit higher income groups who would be likely to purchase the EV even in the absence of, or with a reduced subsidy (Diamond 2009). Second, subsidies are a rather inflexible mechanism that are not easily adapted to changing market and economic conditions. Although a subsidy at first may influence a number of consumers to purchase EVs, it is difficult to assign the proper monetary threshold and to adjust it over time to attain the desired level of EV uptake. Finally and most importantly, a far-reaching subsidy that helps to create a large demand for EVs will put considerable economic strain on the Chinese treasury funds.

Instead, a tax on gasoline is the soundest government policy to facilitate the domestic consumption of EVs. Diamond conducted a study comparing government subsidies to gasoline prices and found that the gasoline prices were a much more relevant factor in impacting the uptake of hybrid vehicles in the U.S. Diamond's regression failed to show any significant impacts from subsidy grants on the rate of hybrid vehicle purchasing, while the price of gasoline and the rate of hybrid purchasing were highly correlated. The study suggested that even relatively minor changes in gas prices lead to significant changes in alternative-fuel vehicle adoption patterns (Diamond 2009). These findings support the conclusion that imposing a government tax on gasoline would be a sounder policy strategy to encourage a higher rate of EV consumption.

As was discussed in the previous chapter, gasoline prices in China are already relatively high. According to studies by Karplus *et al.* (2009), a gasoline price of US$4 and above marked the threshold at which PHEVs and EVs began to make strong economic sense. With gasoline prices in China already hovering around the US$4 mark, the government would only need to impose a small gasoline tax in order to leverage greater EV adoption.

Imposing a gasoline tax has several advantages as a strategy. A tax would likely encourage higher, sustained EV adoption than a subsidy because it would inspire more consumers to consider the long-term investment aspect of an EV; instead of thinking about up-front cost reductions in the initial purchase, consumers would buy EVs as an investment to save money from reduced fueling expenses. A constant, low-level tax could stay in place for an extended time period, and would thus be relevant to consumers over a longer time horizon. Another real benefit of the tax is the benefits it would have for the Central Treasury; instead of draining government funds, a tax would bolster reserves and this revenue in turn could be filtered back into R&D for domestic EV manufacturing, for environmental clean-up, or for other related agendas. The imposition of a gasoline tax is also much more feasible in a nation such as China than in the U.S. or other democratic countries; it would be relatively easy for Chinese government officials to impose a small tax without much dissent or backlash because of the considerable and largely uncontested power of the central government.

Looking at these two aspects of consumer demand, it seems that a widespread uptake of EVs in the near term is a possibility given the right combination of marketing savvy and government intervention. Combinations of government subsidies for EVs and taxes on gasoline have the potential to generate demand for EVs on the basis of economic investment. However, beyond influencing the consumer choice to purchase an EV, there are many considerations that must be taken into account concerning the national infrastructure to accommodate a shift in vehicle fleet to EVs.

Building national EV infrastructure

Accepting the premise that consumers will widely accept and adopt EV models as their primary means of personal transportation, considerations about physical infrastructure accommodations must be taken seriously. For the domestic EV market to flourish, enough charging stations must be strategically built around the country's transportation networks. This section will explore some of the ways in which EV power can be integrated into the transportation infrastructure, and ways in which this process can be facilitated by government and industry.

EV charging technology is still under development, as several different approaches to charging are being investigated for deployment. There are three different power levels that EVs can be charged at; trickle charging takes six to eight hours to complete a charge and is best done overnight, medium chargers refresh a battery in about an hour and a half, and superfast chargers take only twenty minutes to fully recharge a passenger vehicle but suck up substantially more energy from the grid (Dumaine 2010). Despite the high energy demands of this last charging capability, this method is very useful for long-distance drives that require refueling during the trip. Having this array of charging capacities is important for the efficacy of EV deployment because it allows more commuter flexibility. Considering these charging capabilities and needs, infrastructure development needs to accommodate all of these charging variations enough to satisfy commuter demand.

Charging infrastructure becomes a necessity in commuter homes, in parking structures, and strategically placed along transit routes. The majority of urban Chinese live in apartments, thus installing personal recharging devices becomes difficult (Bradsher 2009). Urban planners will need to consider other options for public charging centers that can handle the load of many EVs charging alongside each other. This is a big distinction of China's domestic EV market relative to EV deployment in the U.S. and other nations that are dominated by homeowners. Although this situation allows for more opportunities to coordinate grid systems, as will be discussed later, it also constitutes a considerable hurdle to EV deployment in the initial stages.

Because of the lack of opportunities for private charging stations, there will need to be a widespread provision of charging stations in public parking lots and at other strategic locations within China's transport network. As of 2009, the Chinese government had already mandated that electric car charging stations were to be set up in the cities of Beijing, Shanghai, and Tianjin (Kraemer 2009). This mandate coincided with the central government's plan to distribute EVs to taxi companies and other public transport fleets in major urban centers. The logic behind this policy holds that taxis and other public transit vehicles generally drive set routes, thus it is relatively easy to lay out a series of charging stations that will be widely and reliably used (Dumaine 2010). This policy has thus far been well received by Chinese taxi companies, because as an industry they care more about lifetime operating costs than up-front investments. A BYD electric taxi costs approximately US$40,000 before subsidies, bringing it in at double what a normal taxi would cost. However, the electricity needed to fuel these vehicles costs approximately a quarter as much as gasoline fueling, thus each taxi saves about US$9,000 a year in fuel costs (Dumaine 2010). With a relatively aggressive shift in China's public transit sector to EVs, charging infrastructure will develop rapidly in its wake, thus benefitting the entire commuter segment.

Challenges to developing charging infrastructure

Although charging infrastructure is already being deployed in Chinese cities, city planners still face a formidable challenge in coordinating the effort to deploy a necessary number of charging stations at strategic locations. This task has an added layer of complexity in that EV technology is still very much in fluctuation. Consumer behavior in terms of charging is also largely unknown; will consumers take advantage of superfast charging at higher rates or will they almost exclusively power their transport needs overnight in their local parking garages? One strategy currently under development by car companies and their partners is the development of Smartphone Applications that will assist in guiding the driver to the nearest charging station. This will allay consumer concerns about EV commute reliability, and will make it more appealing for people to charge on the road in between commutes.

Another obstacle to the rapid deployment of EV charging stations is the enormous cost to generate this new infrastructure. Song *et al.* (2010) estimate that the government would have to spend RMB 380 million (US$57,179,000) to construct one-thousand charging stations. Building the initial EV infrastructure will thus represent a substantial up front cost for the Chinese government if it wishes to promote the EV market. However, after the government deploys the initial outlay, private industry will most likely be quick to step up and fill in the gaps, and may eventually overtake operation of the government established charging stations.

If the EV market truly experiences success and growth in China, there will be enormous opportunities for private companies and utilities to make money off of charging stations. In 2009, the electric transport and infrastructure company Ecotality entered into a joint venture with the Chinese firm Shenzhen Goch Investment to establish a manufacturing base for their products in China. If Ecotality's manufacturing takes off, there will be a strong local supply of EV charging stations ready for installation in the country (Kraemer 2009). Ecotality and firms with comparable businesses stand to profit enormously from a surge in Chinese EV use. Beyond these manufacturers, utilities that provide power in China will find a new market in these EV charging stations; they may take over operation of government established charging stations, or commission their own. Earlier this year, the State Grid Corporation – China's largest electric power provider – began constructing charging stations for passenger vehicles and public buses in the cities of Beijing, Shanghai, and Tianjin (Song *et al.* 2010).

As utilities enter the EV charging space, the question of how electric charging will be paid for is also raised. The first element of this consideration is what system of payment consumers will conform to at the station. In developing its charging stations in the U.S., Ecotality is experimenting with different models of payment; it has yet to determine whether it is best to charge consumers per charge, or if the company should create membership plans for users who charge their cars at multiple Ecotality stations (O'Grady 2010). Beyond determining the method of payment, complications with assigning the price may arise depending on how much of the charging sector is controlled by government, versus private companies such as Ecotality, versus public utilities such as the State Grid Corporation. If utilities end up assuming the majority of the charging market, there will need to be a system of government oversight extended to ensure fair rates. As the charging station market grows and evolves, there are likely to be many regulatory issues that will need to be shaken out over time.

An alternative to charging stations: battery trade-ins

Based on the current trajectory of infrastructure development, it appears the charging stations will assume the primary role of powering China's EV fleet. However, it is worth noting the alternative to installing a far-flung network of charging stations, which may ultimately be more consumer-friendly. The primary method of fueling an EV will continue to be the overnight slow charging, but for EVs in transit, battery trade-in stations may offer a quicker way for consumers to get more mileage out of their vehicles without having to stop for a number of minutes to receive a fast charge at a nearby charging station.

Battery swapping stations are still a new idea relative to the charging station, and swapping technology still has some distance to go before it can be made a reality. In spite of this, it is still worth looking at the potential developments in this sector, which could result in advancement for the EV industry in the future. Currently, the Chinese oil company CNOOC is exploring battery-swapping stations that allow an EV to drive in, drop off its depleted battery, and drive off with a fresh battery in less than a minute (Dumaine 2010). From a convenience point of view, this option could be the future for EV powering.

Despite its advantages, battery swapping is not a viable option currently because of a lack of standardization in EV batteries. Yasuaki Hashimoto, the president of Nissan China, cites the issue that in many passenger EVs, batteries are unique in shape and weight to accommodate the particular vehicle model they are installed in (Dumaine 2010). To allow for easier battery switching, EV manufacturers will need to converge on greater standardization of battery types and designs. However, before this happens on the passenger vehicle front, Hashimoto believes there are great opportunities for battery trade-in stations to be launched for use in the public transit sector (Dumaine 2010). Once again, because buses and other public transit vehicles have set routes and the entire fleet could conform to a single model, battery switching could easily be implemented. If battery switching proves to be an efficient and feasible system for public transit, it may eventually find its way to the mainstream passenger vehicle EV.

EV infrastructure and the Smart Grid

When discussing the charging infrastructure related to EVs, it is also important to consider how this new infrastructure could figure into designs for a Smart Grid. As part of China's heavy push towards modernization, urbanization, and technological development, the creation of a Smart Grid system, at least in the country's big cities, is not far off on the horizon. China's state-owned utilities and giant oil companies are already putting their weight behind the initiative to construct a Smart Grid system, and the integration of charging infrastructure for EVs plays a large role in this network (Dumaine 2010).

EVs could be hugely beneficial for integrating the elements of the Smart Grid to make them run smoothly. EV batteries can act as energy storage devices, thus they have the potential to play a vital role in peak load shifting. Integrating EV batteries into the grid would smooth out the variable generation from wind and other renewable energy sources, thus opening up the grid to more intensive clean energy usage (Peterson *et al.* 2010). The integration of EVs changes the electricity supply system from a one-way delivery system to a two-way delivery system; this is called *vehicle to grid*, or V2G. For cars charged at night, but not used during the day, the charged battery can be used to displace a consumer's heavy household load during peak hours (Brown *et al.* 2010). EV batteries thus provide a reserve of stored energy against unexpected power outages (Peterson *et al.* 2010). These features all suggest that integration of EVs into a Smart Grid could have very positive effects on efficient energy usage and national energy planning. The one caveat to this comes out of the fact previously discussed about the general lack of in-house charging stations; combination parking and charging stations for apartment complexes will need to be designed such that V2G can be applied to allow for the transfer of electricity between a specific car and its owner's apartment.

Overall, the widespread integration of EVs into the Smart Grid system represents a great advantage to the running of the electricity infrastructure, however, it is also worth noting that switching to a fleet dominated by EVs will put added pressures on electricity demand. Due to China's existing robust electricity generating infrastructure, meeting energy demands even with a large number of EVs should not be a big concern; even so, surges in demand will still need to be managed, which again highlights the need for the Smart Grid to regulate energy demand efficiently (Brown *et al.* 2010). This creates a need for in-building or in-home smart metering. Smart Meter devices can monitor patterns of electricity load for specific buildings and signal the prime times to plug EVs into the grid. There are several simple, low cost options that can be employed, for example, the ZigBee based home automation communication network (Tse *et al.* 2010). These smart meters will play an increasingly important role in apartment complexes, to help coordinate energy demand when there is a larger network that needs to be coordinated.

To conclude, the widespread deployment of EVs in China's urban centers presents both the formidable challenge of installing sufficient charging infrastructure, while also presenting the opportunity to coordinate with and benefit the installation of a Smart Grid network. The Chinese government is already on its way to investing in the development and deployment of the necessary infrastructure, the primary variables thus become how quickly this can be accomplished and how efficiently. Private industry will also play a leading role in the successful implementation of this infrastructure, and there are bound to be ample market opportunities for firms to capitalize on this new technology through charging station design, battery switching operations, smart metering, and more.

CHAPTER FIVE

CONCLUSION: RISKS AND REWARDS OF ELECTRIC VEHICLE PROLIFERATION IN CHINA

The rapid pace of innovation and the growing widespread interest in EVs signals the potentiality for the successful development of an EV manufacturing sector and consumer base in China. One goal of this paper has been to chart the various benefits China can hope to accrue by encouraging EV manufacturing and local deployment. In terms of developing a local EV industry China stands to reap the economic rewards of a robust emerging industry that has the potential to provide both highly technical research and engineering jobs, and also large volumes of low-skill manufacturing jobs. Looking then to the benefits of consumer uptake, China stands to gain from reduced local air pollution, in addition to decreased contributions of climate change causing carbon dioxide emissions. China will also benefit from reduced dependence on foreign oil, as an EV fleet can draw instead from electricity powered by the nation's extensive coal reserves.

Beyond citing the aforementioned benefits of Chinese EV production and adoption, the paper has gone on to discuss the various obstacles and opportunities facing the adoption of these goals. For Chinese automobile manufacturers seeking to enter the EV market, there is an interesting mix of factors that will determine their success on a domestic and international stage. In terms of technology, the Chinese have made considerable progress in batteries, yet their automobile engineering on the whole lags behind that of U.S., European, and Japanese car companies. China also has the opportunity to drive down the cost of production for their models through low labor cost and vertical integration strategies. The greatest challenge for these Chinese firms will be to develop reputability and positive perceptions around their products, which historically have been viewed as unreliable, or else have lacked the appeal of a luxury brand.

On the consumer adoption front, there are a number of hurdles to widespread adoption. A considerable challenge for EV manufacturers will be to convincingly market EVs to the Chinese consumer. Pricing strategy will certainly fall under this task, but Chinese government incentives in the forms of subsidies or taxes on gasoline may give consumers the incentives they need to retire their internal combustion engines in favor on an EV. The government can also be highly influential in terms of developing the nation's infrastructure to accommodate EVs; creating an adequate number of roadside charging stations and integrating home charging stations into a Smart Grid will create a national infrastructure conducive to EV purchasing. The Chinese government has already demonstrated a level of commitment to ensuring the success of EV uptake domestically, which indicates that many of these challenges may be met in the near future.

Due to the extensive infrastructure demands associated with national EV adoption, pursuing both a demand-side and a supply-side EV policy represents an enormous capital investment. From this standpoint, despite all of the potential benefits, there is still a great degree of risk wrapped up in this proposal for the government's investments, the Chinese automobile industry, and all the firms that jump into the charging station and Smart Metering industries. If Chinese auto companies are not able to command any significant market share at home or in lucrative Western markets, they may have to reposition by pursuing dominance in India or other markets that may demand extremely low costs but except less reputability and lower quality. Another option is for Chinese firms to pursue stronger ties and partnerships with American, European, or Japanese companies, ceding control over engineering and branding in favor of offering manufacturing opportunities in China.

It is also possible that even if China seeks to reap the environmental and energy security benefits of transitioning from an internal combustion engine automobile fleet, that EVs will prove not to be the chief technology ultimately adopted. Cars powered by diesel or some other alternative clean fuel may turn out to be the technological future for passenger vehicles. There is also the potential for public transit to dominate transportation options in urban centers. Although passenger vehicles represent an important means of transportation within Chinese cities today, there has been rapid development of public transportation infrastructure, which may indeed rise in prominence to the point where EVs become a negligible part of the transportation mix. These possibilities illustrate that despite the gathering momentum behind EVs, the actual market outcome is still far from certain.

Despite the level of uncertainty, an in-depth look at the issues facing the EV market in China is largely encouraging. If the Chinese government continues to provide its support for the industry, it is very possible that China could provide a world-leading model of a national transportation network modeling a path to a clean energy future. As China's economic growth continues and its global prominence grows, a highly modern, electrically-powered and Smart Grid integrated transportation system will reflect well on the country's status as a newly developed nation, and may motivate other countries around the world to follow a similar path.

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