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Toward Electric Cars and Clean Coal: A Comparative Analysis of Strategies and Strategy-Making in the U.S. and China

EV CHAPTERS

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Chapter 3
Summary of Current Strategies and Prognosis of U.S. and Chinese Strategy-Making

The four student reports (chapters 4-7 in this monograph) are studies based on a research design that compared the strategies and the strategy-making processes of the U.S. and Chinese governments with respect to the development and adoption of the electric car and clean coal technologies. The aims of the present chapter are twofold. First, we summarize, in the next section, the substantive research findings of the four studies concerning the current U.S. and Chinese *strategies* with respect to the electric car and clean coal. Second, we further analyze, in the following section, our findings about U.S. and Chinese governmental *strategy-making processes*. Informed by that analysis, we make a prognosis of U.S. and Chinese governmental strategic actions concerning the electric car and clean coal technology in the next five-to-ten years. We end the chapter with some overall conclusions and their implications.

U.S. and Chinese Current Strategies: A Summary of Research Findings

A key premise of our seminar is that the reality of strategy is manifest in *strategic actions* rather than assertions (strategic rhetoric). Hence, we asked the students to pay special attention to strategic actions; that is *consequential actions* demonstrating real commitment[1] on the part of the U.S. and China with respect to the development and adoption of the electric car and clean coal technologies. Below we summarize what we believe are these real current strategies.

Current U.S. strategy related to the electric car and future needs. The study reported in chapter 4 of this monograph confirmed that widespread electric car adoption in the U.S. is necessary to reduce America's reliance on imported fossil fuel, reduce the nation's largest source of carbon emissions, and ensure national transportation security. The study's findings suggest, however, that the government's current strategy, focused on becoming the technology leader in the electric car market, is unlikely to make any significant impact on achieving that result. Instead of such a technology "push" strategy, this study recommends a market "pull" approach, which would entail the government creating incentives for companies to put electric cars in the hands of consumers and for consumers to purchase electric cars. Such policies should include an electric car technology production tax credit, more stringent CAFÉ standards, and on the consumer side, continuing tax credits and non-monetary incentives such as access to HOV lanes. In other words, U.S. government policies should be aimed at building demand for electric cars. Also, the U.S. should invest in Li-ion battery R&D, assure IP ownership, and allow some participation in the advancement of battery technology and production. In addition, the U.S. should clearly target power electronics and systems integration as realistic targets for U.S. leadership.

China's strategy related to the electric car and future needs. In contrast, the study reported in chapter 5 finds only limited support for electric car adoption in China by government agencies such as MIIT and MOST, and essentially none by consumers. Instead, electric car production is an issue of automobile sector competitiveness, as Chinese manufacturers target the U.S. for export of full electric cars as well as batteries. This study also finds that China is well positioned

[1] Burgelman, R.A., *Strategy is Destiny: How strategy-Making Shapes a Company's Future*, New York: Free Press, p. 4.; Grove, A.S., *Only the Paranoid Survive*, New York: Double Day, 1996.

to lead in these areas due to government support for automotive production, China's comparative advantage in low-cost manufacturing at scale, and leadership in battery technology. In fact, China is now the world's dominant Li-ion battery manufacturer, and the Chinese Academy of Science currently leads the world in energy storage and Li-ion peer-reviewed publications. The leadership position of China is likely to persist as over time Li-ion battery manufacturing will be commoditized.

U.S. and Chinese Strategy-Making Processes: A Prognosis

Our four studies also provided insight in the *strategy-making processes* of the U.S. and China. The differences between the strategy-making processes of the two nations can be further discussed in terms of two key dimensions: (1) the degree to which top management's strategic decision-making power is concentrated rather than distributed throughout the organization, and (2) the degree to which top management is able to get all the relevant parties to execute simultaneously rather than sequentially. Appendix 1 briefly discusses four types of strategy-making processes generated by these two dimensions.[2]

Using these two dimensions of strategy-making processes and taking into account the contextual differences facing the U.S. and Chinese governments, we develop the following predictions about the evolution of the strategy-making processes of each government in relation to the development and adoption of the electric car and of clean coal technologies.

Future U.S. strategy-making related to the electric car. Having currently some 250 million cars on the road implies enormous U.S. dependence on foreign oil. Hence, the electrification of the transportation industry is inexorably becoming a high national security priority. The urgency of this, however, will depend critically on the price of foreign oil. Hence,

> Prediction 1a: If the price of oil moves and stays above $150/Bbl, a clear and present national security threat will move the U.S. government to concentrate strategic decision-making and to force all relevant parties to simultaneously help implement a national strategy of scaling up electrification of the transportation sector in the next 5-10 years (a move toward the "rational actor" model).
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> Prediction 1b: If the price of oil stays below $150/Bbl, the U.S. government will continue to allow strategic decision-making to remain widely distributed with various interested parties simultaneously competing for government resources in the next 5-10 years (stick with the "internal ecology" model).

[2] These are: (i) the "rational actor" model (concentrated strategic decision-making and simultaneous action), (ii) the "bureaucratic" model (concentrated strategic decision-making and sequential action), (iii) the "internal ecology" model (distributed strategic decision making and simultaneous action), and (iv) the "garbage can" model (distributed strategic decision-making and sequential action).

Future Chinese strategy-making related to the electric car. Chinese strategy-making with respect to electrification of its transportation sector is likely to be triangular in the next five-to-ten years. Firstly, through past investments China has achieved world leadership in battery technology and manufacturing, which provides it with a competitive advantage to capitalize on the potentially enormous opportunity of supplying the emerging global electric car industry. Hence,

> Prediction 2a: The Chinese government will concentrate strategic decision-making power and vigorously orchestrate simultaneous action of all relevant parties involved in implementing an export strategy to supply batteries to the U.S. and Europe as these regions are forced to scale up their electric car industries in the next 5-10 years (move toward the "rational actor" model).

Secondly, as it becomes an industrial and military superpower, needs to develop higher-value employment opportunities for its vast and increasingly educated labor force, and needs to accommodate the population's demands for affordable means of transportation, China will be strongly motivated to develop its own internal combustion (ICE)-based automotive industry. Hence,

> Prediction 2b: The Chinese government will concentrate strategic decision-making power and vigorously orchestrate simultaneous action of all relevant parties involved in implementing the development of an automotive industry that can market very cheap (<$3,000) ICE-based cars to its own population and perhaps other parts of the developing world (Vietnam, Thailand, and others) in the next 5-10 years (move toward the "rational actor" model).

Thirdly, having only some 37 million cars on the road for a population 4.5 times that of the U.S. implies that electrification of the Chinese transportation sector is still a very low priority. This suggests that the strategy-making process of China will most likely not pay much attention to electric car adoption in the foreseeable future. Hence,

> Prediction 2c: If the price of oil moves and stays above $150/Bbl, the Chinese government will continue to concentrate strategic decision-making power with respect to electrification of the transportation sector but will also allow the various government bureaucracies to compete among each other for resources and influence, which will delay adoption of the electric car during the next 5-10 years (stick with the "bureaucratic" model).

Future U.S. strategy-making related to clean coal. With enormous domestic coal reserves and

Conclusions and Implications

Based on our analysis of current U.S. and Chinese strategies and our prognosis about the strategy-making process of each country with respect to the development and adoption of the electric car, our overall conclusion is that the transformation of the U.S. transportation sector is likely to continue during the next 5-10 years, but probably more slowly than currently anticipated. The key driving force will not be the U.S. government, but rather major incumbent automakers, such as Nissan and Renault, who have secured internal access to critical new battery technology as well as cooperative agreements with national, regional and local governments in different parts of the world which are important for supporting infrastructure development. Only if oil prices again rise rapidly and stay at very high levels will the electric car adoption process in the U.S. accelerate. In that case, the early global movers may have significant advantages, based on economies of scale and economies of learning, to capitalize on a rapidly expanding US market opportunity. We also conclude that the Chinese electric car market opportunity during the next 5-10 years will remain quite small, but that the leadership of Chinese companies in battery technology and manufacturing will open up strong export opportunities if indeed the US electric car market takes off more rapidly.

Appendix 1: Models of Strategy-Making in Complex Organizations

In chapter one, we discussed a model of the organizational strategy-making process that distinguishes between induced and autonomous strategic initiatives to compare strategy-making in the U.S. and PRC. As noted there, top management sets the corporate strategy and induces strategic actions by lower-level leaders that are aligned with it in order to exploit opportunities in the familiar environment. The autonomous strategy process, in contrast, explores new opportunities that are outside the scope of the existing corporate strategy, relate to new environmental segments, and are often based, at least in part, on new distinctive competencies. An important top management responsibility and challenge is to balance resource allocation to the induced and autonomous strategy processes over time; in particular the scaling up and vectoring of resources related to autonomous initiatives that demonstrate viability (a process we call "strategic context determination").

Taking into account the existence of induced and autonomous strategy processes, the overall strategy-making process of a complex social system can be further characterized in terms of two key dimensions: (1) the degree of *concentration (versus distribution) of strategic decision-making powe*r, and (2) the degree to which *strategy execution involves all relevant parties simultaneously (or sequentially)*. The combination of these two dimensions makes it possible to integrate into one conceptual framework four organizational decision-making models previously developed in the literature. Figure 1 shows these four strategy-making processes.

Figure 1: Models of Strategy-Making*

		Strategic Decision-Making Power	
		Concentrated	**Distributed**
Mode of Execution	**Simultaneous**	**RATIONAL ACTOR Model****	**INTERNAL ECOLOGY Model******
	Sequential	**BUREAUCRATIC Model*****	**GARBAGE CAN Model*******

*Burgelman, R.A., *Strategy is Destiny: How Strategy-Making Shapes a Company's Future*, New York: Free Press, 2002: 4-6.

** Also called "Model I" in Allison, G. and Zelikow, P., *Essence of Decision: The Cuban Missile Crisis*, 2nd. Ed., New York: Addison Wesley Longman, 1999.
*** Also called "Model II" in Allison and Zelikow, *ibid*.
**** Burgelman, R. A., "Internal ecology of strategy-making and organizational adaptation: Theory and field research." Organization Science, 1991: 239-262. The internal ecology model is perhaps closest to Allison and Zelikow's Model III: "governmental politics."
*****March, J.G. and Olsen, J.P., *Ambiguity and Choice in Organizations*, Bergen, Universitetsforlaget, 1976.

Rational actor model. A comprehensively rational top management (individual leader or leadership team) formulates the overall strategy and is able to get all the interdependent actors in the organization to simultaneously engage in the actions necessary to implement it. In this model, there is strong alignment between strategy and action. It is often viewed as the ideal type. However, it may be most effective to respond to environmental dynamics that can be reasonably well anticipated and influenced. It may also be the best model for coping with a "clear and present danger" or for exploiting an extraordinary opportunity. While a comprehensively rational top management is in principle able to effectively balance induced and autonomous strategy processes for some period of time, they are likely to eventually start favoring the induced strategy process.

Bureaucratic model. In this model the overall strategy is still formulated by a comprehensively rational top management, but implementation is less immediate because various parts of the organization are independent of each other and translate the strategy in terms of the logic of their own operations before taking action to implement it. This model has advantages in slow moving environments because each part of the system has time to optimize its strategic actions in light of the overall strategy. In rapidly changing environments, however, it will lead to sluggish execution of the overall strategy. While autonomous strategic initiatives will undoubtedly spring up in different parts of the system, scaling them up will be difficult. By default, the induced strategy process will become dominant.

Internal ecology model. This model views organizational-level strategy as the result of successful strategic initiatives of interdependent actors (individuals or groups), who are in a position to commit the organization and who continuously try to do so. In this model, strategy-making is a highly dynamic process that capitalizes on anticipated and unanticipated variations in the internal and external environments. It views the strategy-making process as constituting an opportunity structure for strategic leaders in the organization, but one in which individual opportunity seeking is constrained, to some extent, by the imperative of organizational survival. This model is most effective in highly uncertain, opportunity-rich environments. The autonomous strategy process is likely to be dominant here. Coherence of system-level strategic action depends on the characteristics of the internal selection environment.

Garbage can model. In this model, strategy-making results from various independent actors taking action as a function of the sequence in which problems, solutions, and decision opportunities arise. The effectiveness of system-level strategic action depends on the sequence in which problems, solutions, and decision opportunities arise. There is neither an explicit or implicit overall strategy, nor a clear ecological survival force, serving as reference point for determining whether an initiative is induced or autonomous. Hence, by default the autonomous strategy process dominates. Arriving at a coherent overall strategy for the organization is to a large extent governed by chance. The normative implication of this model is to "just hang in there and keep trying."

We realized that this conceptual framework might be useful to predict U.S. and Chinese government strategy-making in the two energy-related areas.[3]

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[3] Note that in the context of our four studies we did not encounter applications of the garbage can model. However, regarding other alternative energy sources, numerous experiments in solar, wind, nuclear, coal sequestration, and so on, continue with no clear winner in sight. Our prediction therefore is that the U.S. government will remain stuck in the "garbage can" model; that is, the government will keep supporting, on a relatively small scale, various technological advances as they come along, but without making any major commitments.

Chapter 4

OUTLOOK FOR ELECTRIC VEHICLES IN THE UNITED STATES*

* This chapter was prepared by Amal Dorai, Sam Fort, Boris Gimond, Eli Gregory, Ben Lenderman, Elizabeth Martin and Graeme Waitzkin.

OVERVIEW OF US AUTOMOBILE INDUSTRY

The American transportation industry today faces a perfect storm of economic, geopolitical, and environmental concerns that threaten its future. The decline of the US automobile industry, the country's increasing dependence on foreign oil imports, and global warming have spurred the Obama Administration to publicly commit the country to developing alternative transportation methods and alternative energy sources as a way of combating these problems and setting a new path for the US transportation sector and economy as a whole.

The most-discussed aspect of the United States transportation sector is the 50-year decline of the Big Three automakers (GM, Ford, and Chrysler) relative to Japanese and European manufacturers. In 1961, the Big Three sold 85 percent of new passenger cars in the US; by 2008, that had declined to 47 percent. This decline is a longstanding phenomenon, and the recent bankruptcies are only the most catastrophic symptom of a problem that should have been dealt with decades ago. However, even in its current wounded state, the American automobile industry is "too big to fail." Automobile sales are $740 billion per year, which represents 5.6 percent of the total economy; when including indirect effects of the industry such as parts sales and support industries, the automobile sector is fully 8-10 percent of the US economy. The consequences of a total industry failure would devastate not only the major automobile states in the Midwest and South, but would quickly spread to the entire economy in its currently vulnerable state.

The geopolitical concerns around the politics of oil are as important as economic considerations in shaping American policy. US oil production has fallen 45 percent since 1985, while imports have risen 320 percent, coming mainly from the Middle East. In 1985, domestic production was 9 million barrels per day and imports were 3 million barrels; today, production is 5 million barrels and imports are 10 billion barrels. The entire US economy is essentially at the mercy of the Middle Eastern OPEC countries.

Finally, the worldwide issue at the center of transportation is the inexorable march of global warming, and the difficulty of coordinating strategies to combat it before it drastically impacts quality of life on this planet. The contentious issue in this arena is between the largest polluters, some of whom are highly developed economies (most notably, the US) and some of which are developing economies (most notably, China). Each of these blocs demands that the other take a leadership role in sacrificing short-term economic growth to address global warming, and the stalemate has delayed any meaningful actions by the global community.

Electric transportation has been put forward as a way of addressing all three of these problems. Internal combustion engines deliver only 20 percent of their consumed energy to their wheels, and can only consume oil-based fuels, while electric vehicles are themselves nearly 90 percent efficient, and are limited only by the efficiencies of the many methods used to generate the electric power used.[4] Costs of electric cars have come down dramatically since the failed late 1990s EV-1 experiment by General Motors, led largely by improvements in lithium-ion batteries which are expected to continue at an ~8 percent pace per year.[5] Even if coal, the dirtiest power

[4] Tesla Motors.

[5] Jefferies & Co. Equity Research.

generation technology, is used to generate the electricity used, electric cars cause only half the CO2 emissions of a modern hybrid-electric vehicle like a Toyota Prius. If renewable energy is used to power the car, the transportation can literally be emissions-free. It is this promise of creating a new industry to boost economic growth, while also reducing emissions, which can break the traditional economic/environmental “tradeoff” and create a win-win situation for the country that assumes leadership in electric transportation.

We believe that the electrification of the transportation industry will happen whether or not the US is involved, and that electric vehicle adoption can and will be a strategic component of the United States’ strategy as an economy and a nation. However, the federal government will have to combine a strong long-term vision with tactical execution skills in many different arenas to ensure that America takes a leadership position in this nascent but critical electric vehicle (EV) sector.

STATED GOALS OF US GOVERNMENT

In August 2009, when talking about the Recovery Act, Energy Secretary Steven Chu clearly outlined the three main goals pursued by the government in its energy policy “These are incredibly effective investments that will come back to us many times over – by creating jobs, reducing our dependence on foreign oil, cleaning up the air we breathe, and combating climate change.”[6]

Ensure energy and oil independence in America

A few days after going into office, on January 26 2009, President Obama called for the country to become energy independent, saying the reliance on imported oil posed threats to the country’s security.[7]

However, recent history has shown that the goals stated by the governments can be significantly different from the outcomes in terms of energy dependency. In response to the 1973 oil crisis, US President Richard Nixon launched a foreign oil imports reduction program called Project Independence. However, instead the US has steadily increased its oil imports as a percentage of consumption, and today oil represents over $500 billion per year in imports, or nearly 5 percent of annual US GDP that we are essentially sending abroad.

Increase GDP

The recent crisis of the automobile industry has raised the question of the viability of manufacturing cars in the US. The massive subventions allocated by the Recovery Act to domestic electric car projects tend to prove that the current administration heavily relies on this technology to at least maintain the automobile industry’s contribution to the GDP. "For our nation and our economy to recover, we must have a vision for what can be built here in the future

[6] US Department of Energy.
[7] www.Whitehouse.gov.

- and then we need to invest in that vision," said Vice President Biden. "That's what we're doing today and that's what this Recovery Act is about."[8] .

Furthermore, by subsidizing a number of battery manufacturers, the Government has demonstrated its vision that new economic giants will potentially emerge from the electric car supply chain.

Reduce emissions

A few days before the opening of the Copenhagen Climate Conference, US officials announced that the country will reduce its emissions "in the range of" 17 percent below 2005 levels by 2020, giving the world the clearest blueprint yet of US strategies to cut back.

To support this goal, President Obama has, among other initiatives, set the objective of putting one million plug-in hybrid vehicles on the road by 2015.

EVs TO HELP ACHIEVE THESE GOALS

To solve the enormous transportation and energy security problems America currently faces, we believe the solution is to drive the transition from an ICE-based transportation system to an electric vehicle-based one. The development of a strong EV industry in America accomplishes the stated goals above in three ways.

First, a conversion to electric vehicles eliminates America's reliance on other countries for oil imports. With EVs, the US can fuel its vehicles with electricity instead of petroleum. All of the power generated can come from within America's borders, given the strong supply of electricity generating resources. Simultaneously we can drastically reduce the current account deficit and reduce the potential threat of oil-producing countries to national security.

Second, if the US is able to become a leader at producing EVs domestically, America will be able to re-establish its power as a manufacturing center and create thousands of jobs to replace the ones that were lost in the recent recession. Given how important the auto industry is to the United States, being a leader in the auto sector with innovation in electric vehicles will be an important boost to America's economy.

Third, a conversion to electric vehicles will have an enormous positive effect on reducing CO_2 emissions, as EVs are far less polluting than their ICE counterparts. The emissions produced by an ICE vehicle amount to approximately 1.3 billion tons of CO_2 per year. Assuming electricity is produced by our current mix of generation assets (48 percent coal, 22 percent gas, 30 percent other), an all-electric vehicle fleet would emit approximately 460 million tons of CO_2, or 2/3 less than ICE-based vehicles. Furthermore, if this electricity is produced from renewable sources such as wind and solar (such as is the plan for Better Place), the emissions from EVs drop to zero. Besides cleaning smog-filled skies and reducing the effects of global climate change, we

[8] Recovery Act Announcement, US Department of Energy.

also have the opportunity to assert America as an environmental leader and lead by example for other countries that are contemplating their own policies to combat climate change.

EV Economics

The most significant driver of demand for EVs in our view is making electric vehicles cost–effective compared to the current ICE alternatives. As such there are two main variables that will drive the value proposition of EVs to consumers: the price of batteries, which is the most significant single expense currently in building an EV (~40 percent for the Nissan Leaf), and oil prices, which is the most significant recurring cost for automobiles. We see three potential scenarios for the direction of these variables going forward.

Scenario 1: Status Quo

In our first scenario, battery prices stay where they are today (approximately $750/kWh) and oil prices remain low ($50/barrel, or approximately $2/gallon at the pump). This is an approximation for the status quo. As shown in **Exhibit 1**, Scenario 1, in terms of cumulative annual cost of ownership, this scenario is never compelling for a consumer as prices for a hybrid or fully-electric vehicle is never cost-competitive with the ICE alternative.

Scenario 2: Status Quo Battery, Oil Price Spike

In our first scenario, battery prices stay where they are today (approximately $750/kWh), however oil prices spike to approximately $150/barrel (~$5/gallon at the pump), or close to where prices were in the middle of 2008. As shown in **Exhibit 1**, Scenario 2, in terms of cumulative annual cost of ownership, cumulative annual cost of ownership for EVs and PHEVs eventually becomes more compelling than ICE cars, however the breakeven point is 5 or more years out, which may not be compelling enough to drive consumer adoption.

Scenario 3: Battery Technology Breakthrough

In the second scenario, oil prices remain low ($50/barrel), however innovation in battery development leads to a breakthrough that drops battery prices to half of what they are today (to approximately $375/kWh), which is a price that we believe is very achievable in the next several years given historical cost reductions and current innovations in development. As shown in **Exhibit 1**, Scenario 3, cumulative annual cost of ownership for EVs and PHEVs eventually becomes more compelling than ICE cars, however the breakeven point is 5 or more years out, which in our view is likely not compelling enough to drive widespread consumer adoption.

Scenario 4: Battery Technology Breakthrough and Oil Spike

In our final scenario, we continue to assume that innovation leads to $375/kWh battery prices, however in this case through increases in oil prices driven by supply/demand imbalances and/or an additional carbon/gas tax in America, price at the pump goes to $5/gallon (equivalent to ~$150/gallon oil). As in **Exhibit 1**, Scenario 4, cumulative annual cost of ownership is significantly favorable for EVs and PHEVs, with a breakeven point of less than 2 years. This value proposition we believe is extremely attractive to customers and would lead to virtually a complete transition to EVs from ICE.

INDUCED ACTIONS TO SPUR EV INDUSTRY

The analysis above shows that the current cost of batteries is prohibitive for mass consumer adoption. Analysis by the Rocky Mountain Institute (RMI) yields an experience curve for production of lithium-ion batteries, however.[9] As manufacturing increases, "learning by doing" will result in a significant price drop: the cost of these batteries is expected to drop by half over the next ten years. Although batteries are prohibitively costly at the present, increased production will drive the industry down this experience curve. As prices drop, demand will continue without additional government incentives. Support will be needed to bring the industry to this point.

From innovation to mass adoption

At a high level, the automotive industry can be divided into four phases:

1. Research and development
2. Product scaling
3. Mass production
4. Consumer adoption

To drive the industry and allow for technical leadership, financial support is needed at every level. Seed money is needed to fund R&D and break current technology barriers, and fuel efficiency regulations are necessary to drive automakers research initiatives on their own. As new technologies are developed, automakers will require additional funding for the capital-intensive scaling process. As the market is ready for mass adoption, funding will be required for mass manufacturing facilities. Finally, incentives will be needed on the consumer side to increase adoption. The United States government currently has initiatives along these four stages. Here we review the induced and autonomous initiatives in place and compare them to relevant private and public spending on similar programs.

Seed phase: Research and Development

At the seed stage, government funds have been provided for battery research and development. The DOE has allocated $11M in funding for division among seven battery technology start-ups and universities, for improvement of battery material performance and decreasing cost (See **Exhibit 2** for breakdown).

To bring this amount in perspective, leading battery manufacturer A123 received $32 million in their first round of funding alone. They have received over $200 million in funding to achieve their position in the battery industry today. Manufacturers such as Ford and Toyota typically

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[9] Anderson, D., "Status and Trends in the HEV/PHEV/EV Battery Industry," presentation at U.C. Berkeley in Summer 2008, Rocky Mountain Institute.

spend from \$5 - \$8 billion annually on R&D.[10] Compared to these figures, \$11 million is not significant.

In addition to providing seed money, the government can stimulate interest in R&D by providing production incentives such as CAFE multipliers. Under new federal regulations, vehicle manufacturers will have to meet fleet averages of 35.5 mpg for all new cars sold. As the current average fuel economy of new vehicles sold is roughly 27 mpg, this will require investment in new technologies for improvements in fuel efficiency. An "EV multiplier" is currently being considered for these standards. Under this system, PHEVs and EVs would be averaged in as 0 mpg vehicles (despite having zero emissions), and the number of EVs produced would be multiplied by 1.2 or 2 to determine the fleet average fuel efficiency. The multiplier would provide an additional incentive for manufacturers to incorporate these vehicles into their product lines, despite their high cost.

It is estimated that it will cost auto manufacturers an average of \$1,100 per vehicle to improve a traditional internal combustion vehicle to meet these standards.[11] The average additional production costs of a PHEV with a 40 mile range are \$9,262; those of an EV with 100 miles of range are \$15,860. If an automaker decided to meet the new standards by adding PHEVs and EVs to his fleet (while keeping the efficiency of all other vehicles the same), the number of vehicles they would need to add depends on the CAFE multiplier. The table illustrates this effect below.

	CAFE multiplier		
Vehicle type	1	1.2	2
ICE	75%	79%	86%
PHEV/EV	25%	21%	14%

As a lower number of non-traditional vehicles will be needed with these multipliers, the average cost to meet the standard per vehicle will be reduced. The effect of the multipliers on average cost can be seen in the table below, in addition to the chart in **Exhibit 3.**

	CAFE multiplier		
Cost	1	1.2	2
ICE	\$1,100	\$1,100	\$1,100
PHEV-40	\$2,270	\$1,972	\$1,293
EV-100	\$3,887	\$3,377	\$2,215

Maintaining a fleet of traditional internal combustion engine vehicles results in average costs of \$1,100 per vehicle. Meeting the standards by adding PHEVs or EVs to a fleet is much costlier in all three multiplier scenarios. It can be assumed that with current battery prices, CAFE multipliers will not provide sufficient incentives for an increase in EV production.

[10] "Viknesh VIjayenthiran," Ford's R&D budget second biggest in the world," *Motor Authority,* October 8, 2007, Ford 2009 annual report, Toyota Motor Corporation.

[11] Ken Bensinger, "Obama Administration Unveils Fuel Economy Rules," *Los Angeles Times,* September 16, 2009.

Product Scaling and Mass Production

Scale becomes the next phase of development. Under the Advanced Technology Vehicle Manufacturing Program, the US DOE allocated funds to develop manufacturing facilities for advanced vehicles and components. Of these funds, $2.6 billion was allotted for electric vehicles, including $529 million for Fisker facilities and $465 million for Tesla. Of the money allocated to Tesla, $100 million will go towards battery manufacturing facilities, allowing production of 30,000 units per year by 2013.[12] Loans provided to Fisker will allow for production of 15,000 cars per year.[13] With annual U.S. auto sales of more than 10 million vehicles, 30,000 units will amount to less than 3 percent. (See **Exhibit 4** for a breakdown of Advanced Technology Vehicle Manufacturing allocation).

In addition to these loans, government funds of $2.5 billion have been provided for battery and advanced vehicle manufacturing facilities. Under the same program however, $5.9 billion in loans were allocated to Ford alone for manufacturing of advanced internal combustion engines.

Consumer Adoption

The final stage of industry is consumer adoption. DOE and the National Renewable Energy Laboratory (NREL) studies have shown that only 14 percent of consumers systematically consider fuel economy economics when purchasing new vehicles.[14] Other studies have shown that when consumers do consider fuel savings, it is often over a time span of only a few years,[15] as opposed to 10 years or the full life of the vehicle. EVs currently have a higher up-front cost, but allow for fuel savings throughout the vehicle life. The failure of consumers to consider potential savings provides a significant barrier to adoption, requiring government intervention to support the industry.

Support in this area can be provided in the form of purchase tax incentives, infrastructure investments, funding for government fleet purchases, and non-monetary consumer incentives. Of the 2009 Federal Stimulus package, $2 billion was provided for individual purchase tax incentives. Individual private purchase incentives for PHEVs and EVs come to $7,500 per vehicle; an additional $600 million was allocated for purchase of government vehicles.

An analysis of the effect of the tax credits can be done by assuming that consumers will change purchase decisions when the net-present value (NPV) over five years is roughly $1,000. It is assumed that the point at which they will switch is normally distributed around this value, as consumers consider several other factors in the decision to purchase a vehicle. The distribution

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[12] Josie Garthwaite, "Tesla Wins $465M in DOE Loans; Nissan Gets $1.6B for Electric Cars," earth2tech, June 23, 2009.
http://earth2tech.com/2009/06/23/tesla-wins-465m-in-doe-loans-nissan-gets-1-6b-for-electric-cars/

[13] Josh Mitchell and Stephen Power, "Gore-Backed Car Firm Gets Large U.S. Loan," *Wall Street Journal*, September 25, 2009.

[14] David L Green, "The Market for Fuel Economy: How Does it Work?" *BESD Seminar.* Oak Ridge National Laboratory, 2008.

[15] Ibid

and cumulative density function of an assumed demand function is shown in **Exhibit 5**. Given this assumption and the learning rate assumptions from RMI as stated earlier, calculations show that the price effect of the tax credit will significantly affect adoption, as shown in the charts in **Exhibit 6**.

Adoption in this scenario has a snowball effect: as increased demand drives increases in manufacturing, battery prices drop, thereby increasing demand. Based on this analysis, we determine that the purchase tax incentives of $7,500 per vehicle will have a significant influence in increased adoption.

AUTONOMOUS ACTIONS TO FURTHER INDUCED ACTIONS

Induced actions from the US government will help in terms of providing the funding and political support necessary to drive the EV industry forward in America. However these measures are meaningless without complementary autonomous actions from startups, private investors, and industry players that will build the companies and technologies we need to drive our electric vehicle future. More specifically, we must have the support of the following constituents: venture capital and private equity investors, auto OEMs, U.S.-based battery companies, and infrastructure players such as major US utilities.

Venture Capital Investing

The autonomous actions of venture capital and private equity investors are crucial to the success of the EV industry in America, as these firms will be the leaders in identifying the technologies and market segments where there exists the greatest potential for value creation in the US economy. Venture investors have been focused on the electric vehicle and advanced battery market since early this decade, however given the capital intensive nature of these businesses, many fewer startups in these sectors have been funded compared to less capital intensive internet and software startups. Venture investing in lithium-ion batteries, the only proven form of advanced battery for EV, has been relatively modest compared to investment in other industry segments.

The future prospects for private investors to increase funding in EVs and advanced batteries is improving given government grants and loan guarantees, however our judgment is that investors will need to see several high-returning exits in this industry before they commit significant additional capital to these sectors.

Automakers

Autonomous actions from the big three U.S. automakers will also be critical in establishing America as a worldwide leader in EVs, given their enormous R&D budgets, established manufacturing infrastructure and years of experience in the industry. To date, GM, Ford and Chrysler have each developed their own EV initiatives. The resources and output they have committed to these efforts remains lackluster, however. For example, GM has committed several billion dollars to developing the plug-in hybrid Chevy Volt, but the company only plans to produce 30,000 of these cars for the first two years after launch, equivalent to 0.18 percent of the company's total sales. Ford has announced plans to create a 100-mile battery-electric vehicle in 2011, but has also only committed to produce 10,000 in its first year. In November 2009, Chrysler decided to effectively disband its electric-drive initiative due to executive order from its new owner, Fiat. Given the dramatic downturn in the US auto industry, the focus on cost-cutting and restructuring under bankruptcy, and the uncertain future around consumer demand for electric cars, our judgment is that the big U.S. automakers will not lead the U.S. to become the world leader in electric vehicles unless more incentives are provided by the government to support EV growth.

U.S. battery makers are another important player whose autonomous actions will drive the U.S. EV industry. Currently there is simply a dearth of US-based companies that have the technology and capabilities to provide batteries for electric vehicles. A123 Systems, based in Massachusetts, is one such provider that has had recent success through an initial public offering in October of 2009. A123 has received loan support from the federal government, which we believe is a step in the right direction, and the company has signed contracts with Chrysler to provide the batteries for their electric vehicles, however the recent Fiat takeover at Chrysler has put this partnership at risk. Johnson Controls, another US-based company, has formed a joint venture with French battery company Saft, however much of the manufacturing of these batteries will take place abroad. All other significant lithium-ion battery companies, including LG Chem, BYD, Sanyo, and others are based abroad and currently have greater scale than their U.S. competitors. Our judgment is that this area has deservedly garnered more focus from the federal government, however must be supported to a greater extent. If we are successful in transitioning our country to electric vehicles from current ICE models, it does little good for us as a country if we are merely replacing our reliance on oil produced abroad to a reliance on batteries produced abroad.

Electricity Infrastructure

Assuming that consumers are convinced of the benefits of EVs, significant cost reductions in battery manufacturing occurs and auto manufacturers are able to design cars that consumers desire, the final outstanding question is whether or not the electricity infrastructure of the United States is capable of handling the increase in demand for electricity from EVs.

Generation Capacity

Given the demand profile for electricity in the United States, significant effort will likely be taken by grid operators to encourage EV charging to occur during the evening when excess capacity is highest and prices are lowest. Even though this is the likely outcome, it is instructive to understand the current balance between electricity supply and peak demand and the number of EVs that could be supported under a scenario where each EV in service connected to the grid at times of peak demand.

As of 2007, the United States had approximately 967 GW of installed generation capacity.[16] At the same time, peak demand was 782 GW revealing excess capacity of 186 GW. Without regard

[16] All figures relating to capacity and demand were provided by the Energy Information Administration

for excess capacity requirements, this 186 GW would represent 37.2 million EVs.[17] Taking into account a 15 percent capacity margin, 13.5 million EVs could be added to the peak demand under current generation capacity. Going forward it is projected that approximately 60 GW of net capacity will be added by 2015, representing the capacity for an additional 10 million EVs. Given projected adoption rates, it is assumed that utilities will be able to add additional generation capacity as needed. As a result of these findings, we have determined that generation capacity is not considered to be a limiting factor for EVs.

Transmission and Distribution

There are currently 1.6 million miles of transmission and distribution lines in the United States. While determining the exact transmission capacity of the network is difficult, we do know that congestion on the network has been steadily increasing over the last decade. In 1998 there were 305[18] Transmission Loading Reliefs[19] (TLRs) and in 2008 that number had increased to approximately 3,300.[20] Over roughly the same time line, 2000-2010, Investor Owned Utilities will have invested over $80 billion in their T&D assets, but it is obvious that a 10x increase in TLRs over the last decade is not sustainable and significant investment will be needed to overcome the current deficiencies in the grid.

According to a report prepared for the Edison Electric Institute,[21] it is estimated that from 2010 to 2030, close to $900 billion will need to be spent on T&D (66 percent spent on distribution assets) to integrate renewables into the grid and to accommodate new technologies such as EVs. As an example of the type of investment in distribution that will likely be needed with the adoption of EVs, one can look at the neighborhood transformer, which currently operates near capacity and supports between 6-12 homes. The average home in the United States consumes 10,500 kWh per year and the use of an EV can be expected to add somewhere on the order of 7,500 kWh of demand per EV.[22] This additional consumption is likely to stress these transformers significantly and additional investment will be required to ensure that neighborhoods do not suffer frequent blackouts.[23] Interviews with utility employees indicate that utilities are aware of these issues and are committing significant resources to resolve them.[24] Given projected adoption rates, it is assumed that utilities will be able to update transformers as

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[17] Assumes that each car requires 5kW when charging, 25 kWh battery and a 5 hour charge.

[18] New York State Energy Research and Development Authority
http://www.nyserda.org/publications/report06-13.pdf

[19] A TLR Procedure is a mechanism that allows reliability coordinators to mitigate potential or actual operating security limit violations and the number during a time period provides a sense of congestion within the network.

[20] North American Electric Reliability Corporation (NERC), Transmission Loading Relief, trend chart.
http://www.nerc.com/docs/oc/scs/logs/trends.xls

[21] http://www.eei.org/ourissues/finance/Documents/Transforming_Americas_Power_Industry.pdf

[22] Each charge requires 25 kWh and each EV is charged 300 times per year.

[23] David Herron, "Planning for the Coming Wave of Electric Vehicles," *San Francisco Examiner,* September 17, 2009.
http://www.examiner.com/x-14333-Green-Transportation-Examiner~y2009m9d17-Planning-for-the-coming-wave-of-electric-vehicles

[24] Interview with Christian Keller on November 2, 2009; interview with former PG&E employee John Stanfield on November 17, 2009.

needed. Given these findings, we have determined that transmission and Distribution is not considered to be a limiting factor.

Charging Stations

The final component of the EV charging infrastructure is the actual EV charging stations. There are currently three companies leading the build-out of the charging station infrastructure. Better Place is likely the best known of the three, but at present they have only announced partnerships with a small number of states and have not installed any of their charging or swap stations. Two other companies, Coulomb and eTec have installed stations in several cities in the United States and the Department of Energy recently granted eTec $100 million to install more than 15,000 charging stations in a partnership with Nissan and the states of AZ, CA, OR, TN and WA.

The cost for each charging station various from approximately $5,000 for a Coloumb station to between $1,500 and $2,500 for an eTec station. The forecast of sales of PHEVs results in approximately 5 million PHEVs on the road by 2020. If we conservatively assume a cost of $2,500 per station and 2 stations per car, the cost of building the charging station infrastructure is $25 billion over the next 10 years, which pales in comparison to the amount that will be spent on generation and T&D assets over the same period. Given these findings, the construction of the charging station network is not considered to be a limiting factor.

THE ROLE OF ACTIVISTS

Activists will likely not play an important role in EV adoption in the US. In general, most activists are in favor of EV adoption, but only a few will have enough influence to help drive change and create widespread adoption of EVs. In our view, the most significant activists that will affect US EV industry are the United Auto Workers and environmental activist groups.

The United Auto Workers are somewhat spilt in their views towards the rise of EVs in the U.S. Some U.A.W members feel that EVs would harm the status quo and jeopardize an already failing industry. Other U.A.W members look at EVs as an opportunity to breathe new life into a dying industry in the US. This group has moderate influence in the decision to adopt EVs and is likely to play a moderate role in determining EVs future in the United States.

Environmental activists are highly organized groups in the EV landscape. Most are proponents of EVs and vary widely in their effectiveness. Some activist campaigns originating from these groups have been widespread and highly effective, however overall their effectiveness in changing the automotive landscape has thus far been moderate at best. However with climate change increasing in global awareness, their leverage may grow leading to these groups becoming much more influential in the future.

WILL WE GET THERE WITH THE CURRENT STRATEGY?

Consumer Adoption

Many signs indicate that the US vehicle market will see a large growth in electric vehicles. The first potential influence is the price of fuel: an increase could allow EVs and PHEVs to be cost competitive with traditional ICE vehicles. The second is the price and quality of batteries: current research efforts by Nissan's alliance with NEC and start-ups such as Amprius are likely to result in a technological breakthrough. The third is government incentives and intervention. The current tax credits are spurring quicker adoption, which result in lower prices as a result of the "learning by doing" effect. In an attempt to meet stated greenhouse gas emission targets, the Obama administration is likely to modify the CAFE system or increase current tax credits in favor of PHEVs and EVs. Finally, autonomous market actions have already begun in response to a new consumer demand for "green" products, such as the Toyota Prius.

Government Investment

Looking at the US government investment in EV technology and EV infrastructure, it appears that while the latter is likely to yield tangible positive results, it is unclear that the former will lead to global technical leadership. Infrastructure investments are both large (~$4.5 billion) and diverse (spread around to regional power authorities). Most importantly, these infrastructure investments are not reliant on technology development, as dollars will flow to projects around upgrading smart grid systems and further build out of physical infrastructure, both known technologies. Unlike infrastructure investments, the outcome from EV technology investments is less clear. While $11million in early science grants and $2.6 billion in production scaling loans for EVs may yield technology advancement, these amounts are insignificant when compared to competitive battery and automobile R&D budgets.

Industry: EV Technology

Currently, foreign battery technology (primarily from China and Japan) is more sophisticated than U.S. domestic production. As long as batteries remain such a higher percentage (~40 percent) of electric vehicle cost, it is likely that foreign players will dominate the EV market. However, as battery costs decline as projected and become essentially a commodity component in EV manufacturing, technology sophistication in battery production will be less of a competitive advantage and a highly fragmented battery supply will likely emerge. In such an environment, one can expect a continuation of the current status quo of the current automobile market fragmentation with no clear dominant company, composed of players from Japan, Korea, U.S. and Europe with both start-up entrants like Tesla, Fisker or Coda, and new foreign players like BYD and Tata.

Industry: EV Infrastructure

As discussed, as much as $900 billion of grid investment is needed over the next 20 years, along with the build out of a widespread charging network for EVs. The US government has allocated approximately $4.5 billion to upgrade parts of the grid through the stimulus package, but it is expected that the responsibility for future investment will be met by autonomous actions of Investor Owned Utilities on the grid side. While these investments are not primarily directly for EVs, grid upgrades will have significant ancillary benefits for EVs including smart metering and grid stability. With regard to charging infrastructure, it is very likely that a combination of grass roots efforts by start-ups and local governments will deliver a charging station network for EVs.

RECOMMENDATIONS FOR AMERICA'S ELECTRIC VEHICLE FUTURE

The current U.S. transportation industry is on an unsustainable course - the reliance on imported fossil fuels and the subsequent carbon emission indicate that a movement towards EV adoption is necessary for U.S. transportation security. The default approach for the U.S. to achieve transportation security is to become the world leader in EV technology. Accordingly, government policies are aligned to support technology leadership in the form of grants for early stage science and loans for existing manufacturers to scale production. The U.S. may eventually be a technology leader, but currently that outcome remains unclear given U.S. technology sophistication in comparison to foreign competitors. Given the market size and projected increases in oil prices, it is more likely that the U.S. will need to become the EV adoption leader.

As such, in order to become a leader in the adoption of EVs, policy makers at all levels of government should consider the following policy goals:

Higher gasoline taxes

Of net importing OECD countries, the United States has the lowest gasoline taxes in the world. By artificially raising the price of oil through a gasoline tax, the government can move more rapidly towards price parity between ICE vehicles and EVs.[25] The obvious obstacle to this recommendation is the political difficulty in passing new taxes. An alternative to raising the national tax might be autonomous movements by motivated state governments to raise gasoline tax to increase state revenues while making their state home to a growth industry like electric vehicles.

Improved CAFÉ standards

In an upgrade the Energy Independence and Security Act (2007) the Obama administration has set a requirement of 35 mpg average for the fleet by 2016. At today's fleetwide average of 25 this represents representing a 40 percent improvement over today's CAFÉ standards.[26] While this is an aggressive target, by simply removing SUVs and light trucks from the product portfolio would achieve this goal, leaving the transportation sector still reliant on foreign oil sources, albeit more efficient. Like the exceptions provided in the current CAFÉ standards for flex fuel

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[25] Australian Institute of Petroleum.
http://www.aip.com.au/pricing/internationalprices.htm

[26] Brent D. Yacobucci, "Automobile and Light Truck Fuel Economy: The CAFE Standards." Congressional Research Service Report for Congress, May 7, 2008,

vehicles, higher weighting for EVs and PHEVs could incentivize auto manufacturers to produce higher volumes.

Demand-side incentives

Non-monetary incentives to own electric cars can help spur demand without taking additional public funds. Incentives like free access to HOV lanes and preferred parking can increase adoption, particularly in high congestion areas.

Incentives for consumer focused businesses

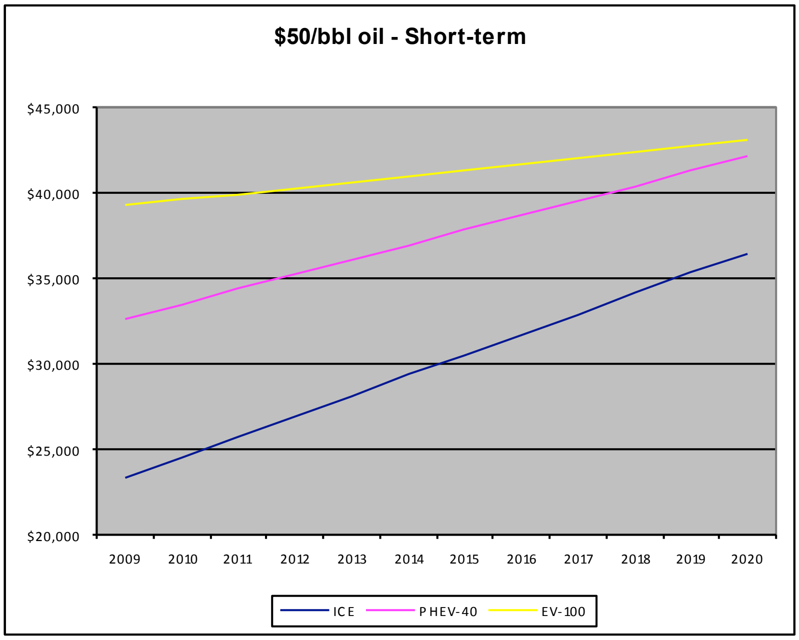
Similar to loan guarantees for EV related science, the government can implement targeting financing or tax incentives for business built around EVs and corresponding infrastructure. Such programs can induce the creation of new businesses or the movement of existing companies, like utility providers, service stations, or retail businesses towards EV related products.

Increase consumer tax credit
The current maximum consumer tax credit of $7,500 often just makes up for the extra cost associated with an EV battery as compared to its ICE counterpart. Any increase in this tax credit could create an advantageous situation for consumers of EVs and would speed EV adoption.

Exhibit 1
Oil and Battery Price Scenarios

Graphs represent Total Annual cost of Ownership; i.e. vehicle is assumed purchase at the end of 2009, and incremental annual costs (fuel, maintenance, etc.) are added cumulatively over the life of the vehicle

Scenario 1



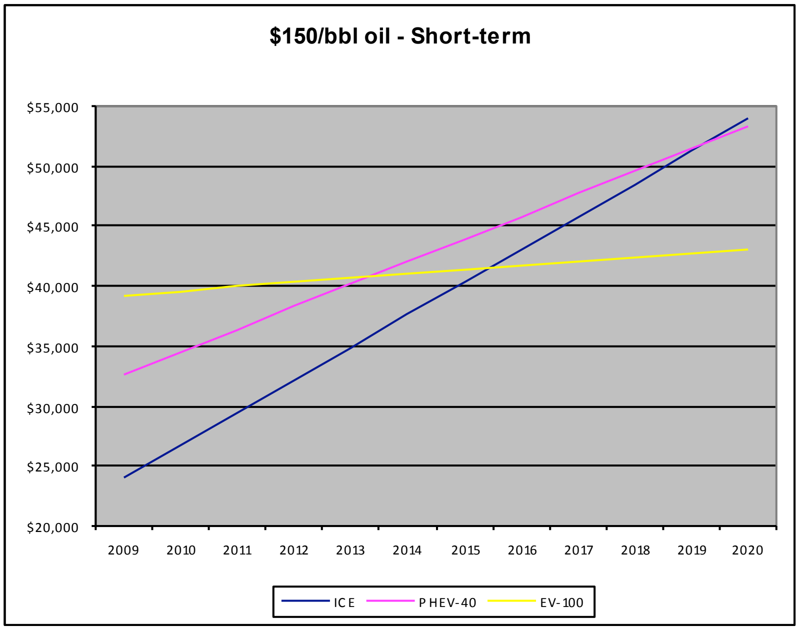
ASSUMPTIONS

- Car life of 11 years / 155,000 miles
- Electricity price of 10.5 cents/kWh
- 27.5 mpg for ICE
- 5.0 mi/kWh for EV/PHEV
- $100/yr maintenance cost for ICE, $75/yr for PHEV, $50/yr for EV
- Oil change cost of $25 per 5,000/10,000 miles for ICE/PHEV
- No discount rate

Source: Created by research paper authors.

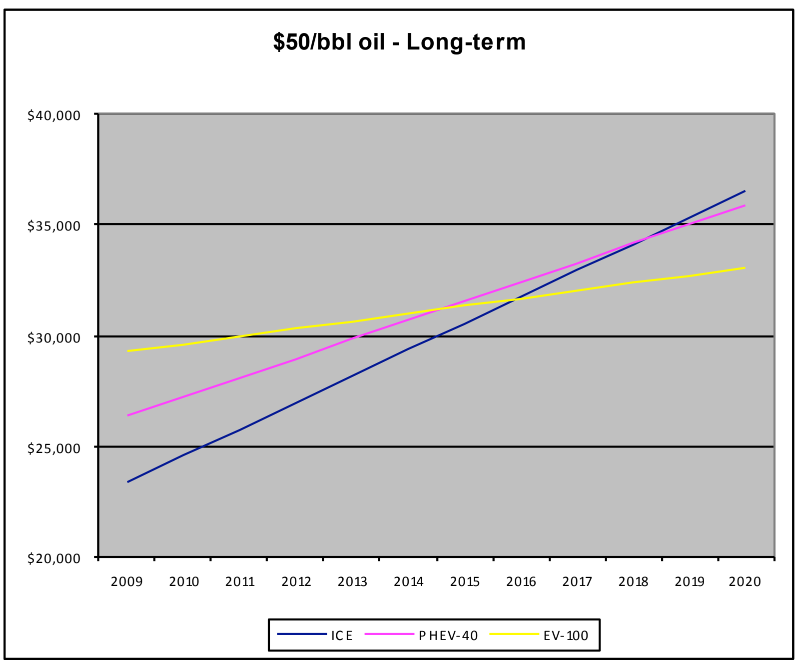
Exhibit 1 (continued)
Oil and Battery Price Scenarios

Scenario 2



Source: Created by research paper authors.

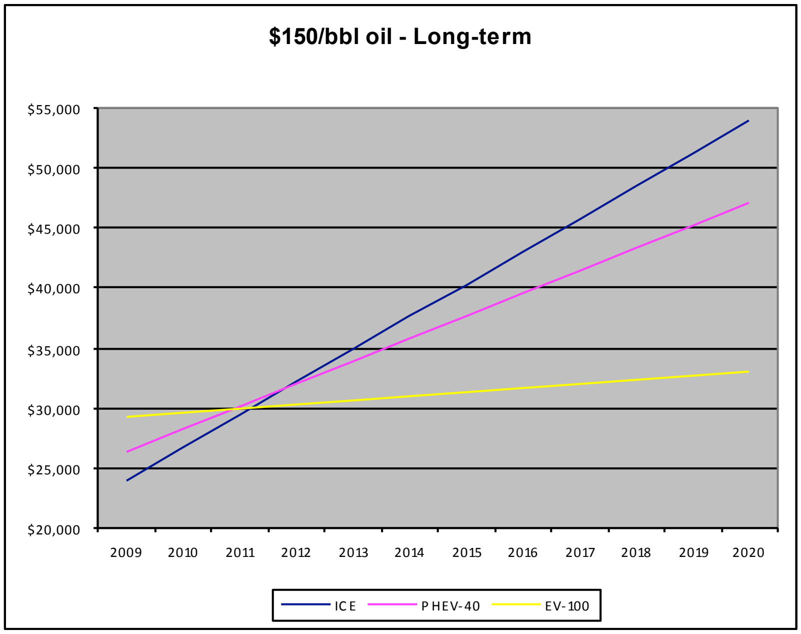
Scenario 3



Source: Created by research paper authors.

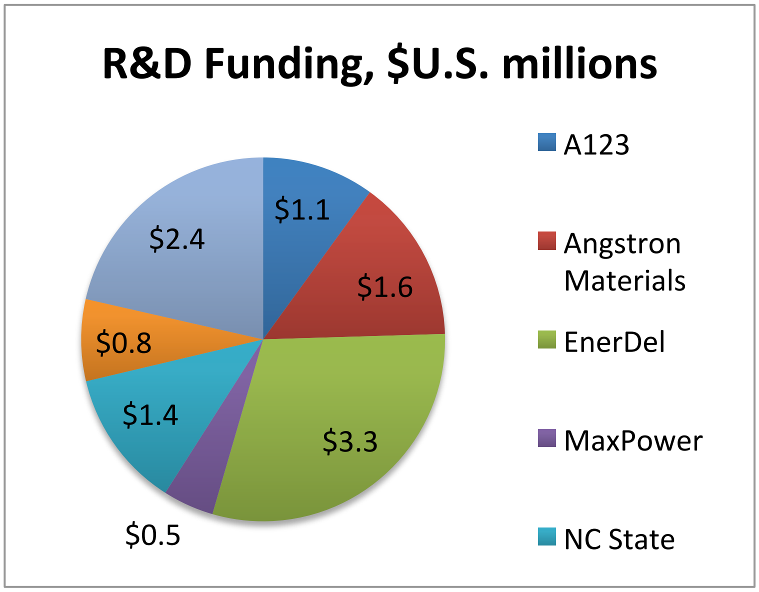
Exhibit 1 (continued)
Oil and Battery Price Scenarios

Scenario 4



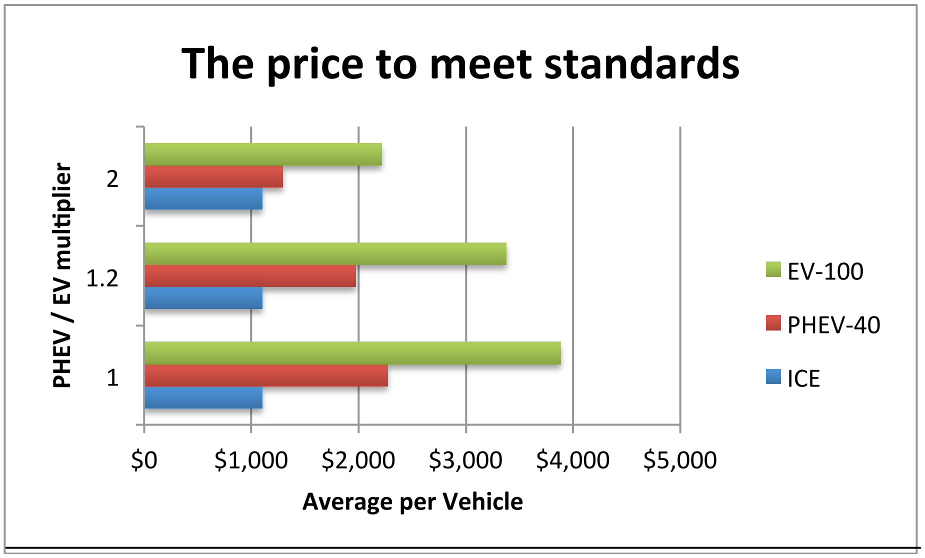
Source: Created by research paper authors.

Exhibit 2
Breakdown of $11B in R&D Funding from US Government



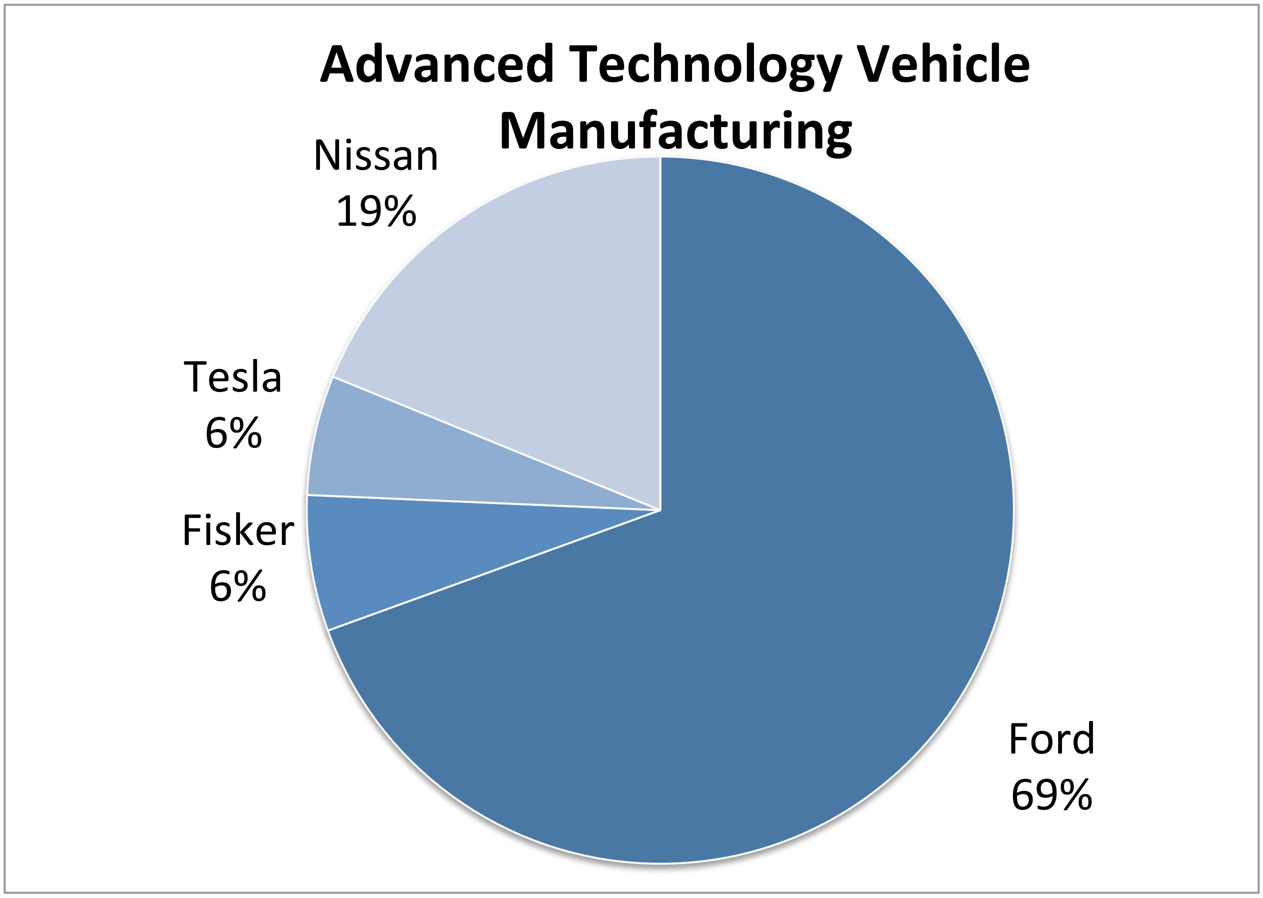
Source: U.S. Department of Energy

Exhibit 3
Effect of Multipliers on Average Cost



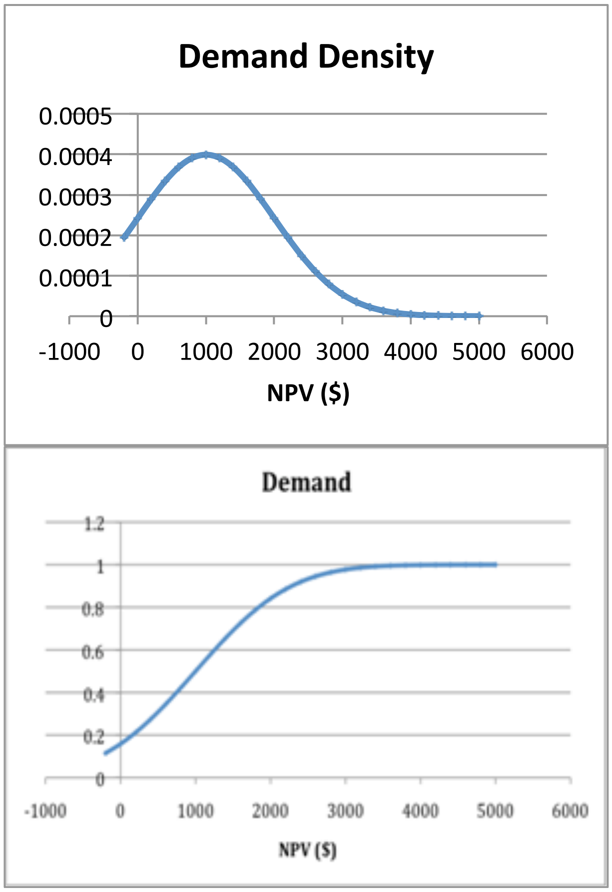
Source: Created by Research Paper authors.

Exhibit 4
Breakdown of Advanced Technology Vehible Manufacturing Allocation



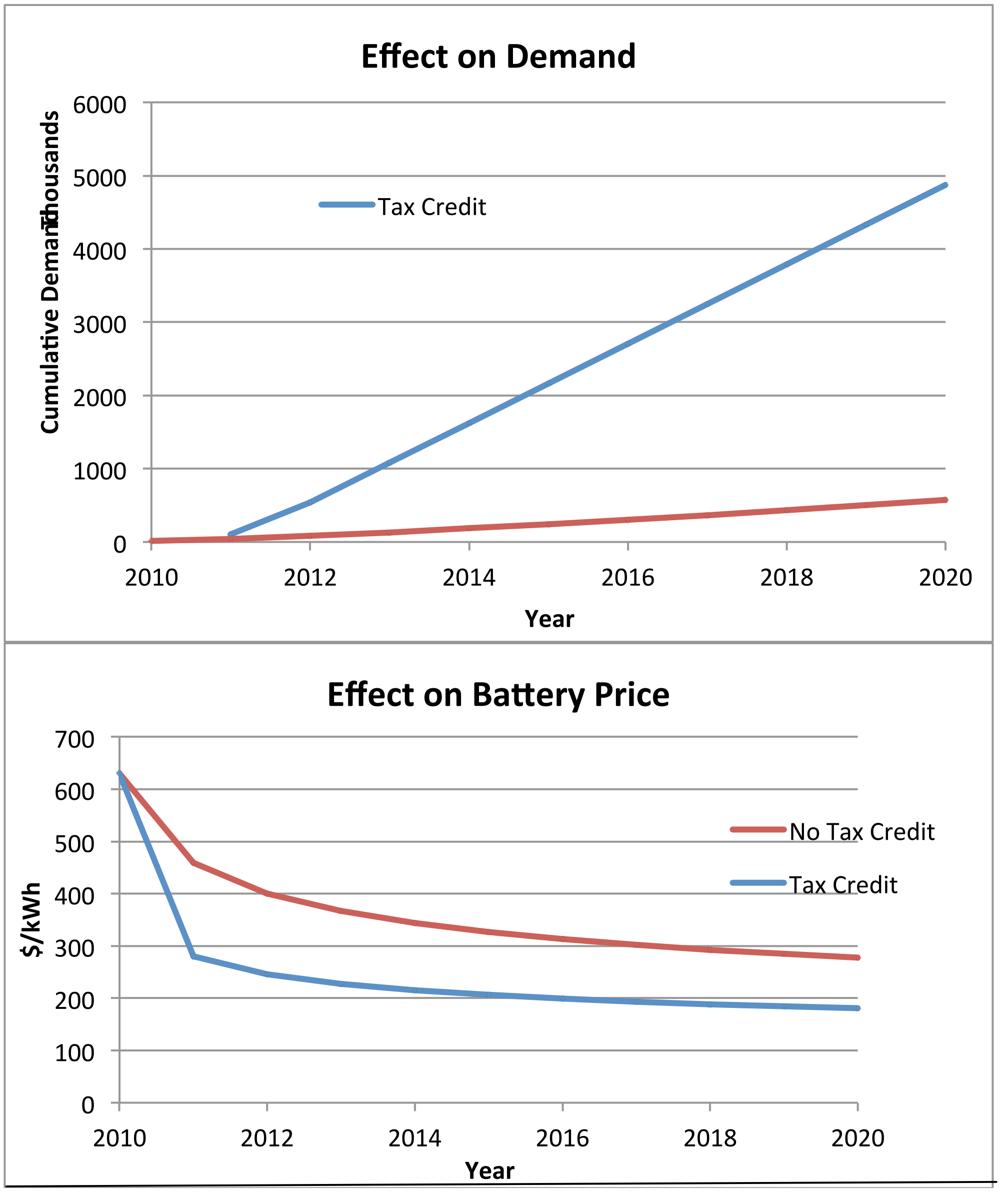
Source:Advanced Technology Vehicles Manufacturing Loan Program, U.S.Department of Energy. http://www.atvmloan.energy.gov/

Exhibit 5
Demand Profile for EVs



Source: Created by research paper authors.

Exhibit 6
Tax Credit Impacts on Adoption



Source: Created by research paper authors.

Chapter 5

PLUGGING IN: THE DYNAMICS OF ELECTRIC VEHICLE ADOPTION IN CHINA*

* This chapter was prepared by Anna Fang, Bofei He, Yohei Iwasaki, Ling Jin, Emily Ma, Michael Ovadia and Thomas Rigo

INTRODUCTION

Over the past decade, China's rapid economic growth has led to an even greater expansion of CO_2 emissions, air pollution and oil consumption. The Chinese economy's contribution to global warming, to social unrest through environmental degradation and to strategic vulnerability through oil imports has not gone unnoticed. For the first time, in 2007, improving environmental quality became a key strategic initiative in the National Development and Reform Commission's Five-Year plan.[27]

The central government's new focus on environmental issues has given advocates of electric automobiles (EV) hope that China will provide global leadership in EV adoption. However, in China, as in the rest of the world, the EV market remains unable to overcome the upfront costs necessary to reach large scale production and adoption. Large scale adoption is not commercially feasible because the cost of batteries that deliver similar performance to internal combustion engines (ICE) is relatively high, while the fully-costed price of owning an ICE automobile remains low. In order to make EVs economically attractive for consumers, the government must provide incentives for EV adoption or manufacturers must deliver rapid innovation that will dramatically reduce the cost of batteries. This paper plans to address these dynamics of potential EV adoption in China by answering two key questions:

1) Are conditions in China currently ripe for near-term EV adoption?
2) In the future, what are the necessary conditions for widespread EV adoption in China?

In order to answer the first question, we analyze three aspects of current conditions in China. We examine:

- The willingness of the Chinese government to take actions to stimulate EV adoption.
- The influence of "activists" to push the government into action.
- The potential for EV adoption through autonomous corporate action with a cross-boundary disruptor (XBD).

Looking beyond the current conditions, we attempt to form a view on the status of EV adoption in China in 2020. In order to approach this task rigorously, we establish three potential scenarios. The purpose of the scenario analysis is to parse out the necessary conditions for EV adoption in China and evaluate the potential of these conditions coming to pass by 2020. The key scenarios we considered were:

- *The status quo* – China, a country dominated by coal-based energy, continues to subsidize gas prices and provides limited incentives for EV adoption.
- *Global environmental concern* – Global environmental concern drives an emission reduction regime, but China maintains a "developing country" exempt status and oil prices stay low.

[27] National Development and Reform Commission (NRDC) People's Republic of China website. http://en.ndrc.gov.cn/

- *High oil prices and global environmental concern* – Global environmental concerns drive an emissions reduction regime globally and oil prices spike.

This analytical process uncovers the conclusion that mass EV adoption in China requires high oil prices *and* technological development *and* government support through consumer subsidies in order to reach scale. Unfortunately, EV adoption is not a strategic priority for the Chinese government in the intermediate future. As a result, the future of EV adoption in China depends on both export markets providing an initial avenue for scaling up EV production and dramatic technological change through a cross-boundary disruptor.

ASSESSING GOVERNMENT EFFORTS TO STIMULATE EV ADOPTION

A Brief Word on Chinese Government Functions and Imperatives

Before analyzing the current status of Chinese government efforts to scale EV adoption in China, a brief overview of Chinese government functions is in order. The decision-making processes of the Chinese government are dramatically different than its American and European counterparts and its workings must be understood in order to follow the logic and conclusions of this paper.

China's government consists of the Communist Party of China, which rules through a one-party system. The party's and the government's highest organ of power is the National Congress of the Communist Party of China. The Congress meets approximately every 5 years as the National Development Reform Commission (NDRC) to set national priorities and direct policy. All aspects of long-term Chinese EV policy ultimately lie in the hands of the NDRC.[28]

China is governed on a day-to-day basis by the Secretariat (Hu Jintao) and the nine-member Politburo Standing Committee, who meet on a weekly basis. The Politburo Standing Committee is made up of party chiefs of major cities, heads of the Central Military Commission and other influential members of the Communist Party. Decision-making at the Politburo level is rumored to be made by consensus. It is important to note that the Politburo leadership is also the leadership of the NDRC. As a result, the Five-Year Plans serve as planning guidelines and the Politburo executes those guidelines on an ongoing basis. The Politburo would oversee EV policy implementation at a high, centralized level.[29]

Policy implementation at a local level is driven by a mélange of ministries and local governments. Key ministries affecting EV development include MOST and MIIT. The role of each of these ministries is discussed in greater detail at a later point, but the key lesson is that multiple ministries have overlapping functions and vie for influence in implementing policy guidelines. Meanwhile, local governments also potentially influence EV adoption by setting auto licensing requirements, local business subsidies and restrictions on products sold locally. Ministers and local government officials are often businessmen and technocrats rather than

[28] National Development and Reform Commission (NRDC) People's Republic of China website. http://en.ndrc.gov.cn/
[29] The Central People's Government of The People's Republic of China website. http://english.gov.cn/

bureaucrats. As a result, the local implementation of central policy guidelines can be characterized by pragmatic approaches that are distorted by the interests of local power holders.[30]

Finally, the Chinese government's central objective – like that all governments – is survival. With the one-party system, however, "survival" means survival of the Communist Party. At its current state of development, the Communist Party's hold on central power is dependent on mitigating social unrest and national security. Social unrest is mitigated by raising the standard of living (monetary and environmental) and by providing employment. National security is maintained through an effective standing army and access to natural resources to supply the economy and military.

A Brief Word on the Chinese Transportation System

As with its government, China's transportation system is organized differently from that of the U.S. or Europe. In order to draw the reader through our analysis and conclusions, it is vital that the reader carries with them a base-line knowledge of the Chinese transportation system.

The core difference between the U.S. and European transportation systems and the Chinese one is the prevalence of automobiles. In China, there are .028 cars per person, rather than 1 and .5 cars per person in the U.S. and Europe.[31] The key mode of personal transportation in China remains the bicycle with 450 million units in 2008.[32] And other significant modes of personal transportation include the electric scooter with 100 million units and the motorcycle with 90 million units. The automobile pales in comparison with only 38 million cars on the road. Meanwhile, commercial transportation is dominated by rail (representing 51 percent of ton-miles) and waterways (27 percent of ton-miles). Truck transportation constitutes 21 percent of ton-miles with 11 million trucks in operation.[33]

The emphasis on rails and light personal transport in China yields a transportation system that is a negligible consumer of energy in the Chinese economy (7 percent) and producer of CO_2 emissions (7 percent). However, the transportation sector does represent 38 percent of China's oil consumption. A closer look at the transportation sector's oil consumption reveals that automobiles represent only 19 percent of the total, while buses and trucks are responsible for slightly more than half of China's transportation oil use.[34] Thus, in order to understand Chinese policy making imperatives around the EV, it is critical to acknowledge that automobiles are, in the near and intermediate term, a tertiary contributor to China's environmental problems and a relatively unimportant consumer of China's natural resources.

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[30] Erica S. Downs, "China's 'New' Energy Administration: China's National Energy Administration Will Struggle to Manage the Energy Sector Effectively," *China Business Review,* November-December 2008. www.chinabusinessreview.com

[31] Central Intelligence Agency website. www.cia.gov.

[32] Jonathan Weinert, et al. "The Transition to Electric Bikes in China: History and Key Reasons for Rapid Growth." UC Davis Institute of Transportation Studies, 2005

[33] "An Overview of China's Transport Sector – 2007,"World Bank Working Paper.

[34] Feng An, "Chinese Transportation Markets and Policy in a High Oil Price Environment," 3rd Transatlantic Energy and Climate Change Policy Workshop, March 30-31, 2006, Auto Project on Energy and Climate Change (APECC).

Assessing the Role of Government Action in Inducing EV Adoption

The rapid adoption of EVs in the near-term (5 years) requires induced action by the Chinese government. The government not only has to play a potential role in making EVs financially attractive to consumer, but the government must also deploy massive grid capacity investments and charging stations. At the current time, the Chinese government's efforts to induce EV adoption remain limited and the government has adopted a "wait-and-see" approach through allowing autonomous development of corporations and technologies dedicated to the EV arena.

If one observes the Chinese government's recent actions, it is clear that there is little interest in the Communist Party to push large scale adoption of EVs in the Chinese markets. At the national level, the 2007 Five-Year Plan provides no quantitative measures of emissions or transportation pollution reduction. Instead, the document is focused on diversifying and reducing the emissions intensity of the Chinese economy. This "emission intensity" language suggests that the central government's focus is not on the small impact that EVs would have on the environment, but rather on the massive impact that shifting Chinese reliance on industry in favor of higher value and lower-polluting industries such as services would have on the Chinese quality of life.[35] The recent stimulus package provides another data point for central government priorities. The $586 billion Chinese stimulus package included $1.5 billion towards low carbon emission vehicles – including hybrids and plug-in hybrids. This figure pales in comparison with the allocation to improving energy efficiency in the rail system ($98.7 billion) and the electricity grid ($70 billion). Similarly, funding efforts for EVs at the ministry-level in China have been minimal. MOST, the ministry responsible for directing R&D in China has set aside $106 million annually for developing hybrids and EVs.[36] MIIT, the ministry responsible for directing established industries such as the automotive industry, recently announced a technology revitalization program that include $1.5 billion for the automotive industry in general.[37]

China's observed strategy of minimal involvement in the EV arena dovetails with the priorities articulated by government agencies in the media. Thus far, goal setting for EVs has been de minims. The most recent government target for "new energy cars" has been set at 0.5 million by 2011.[38] However, most of these vehicles are budgeted to be government fleet and special vehicles. This target is unimportant within the Chinese planning behemoth and "new energy cars" includes hybrids, plug-in hybrids and EVs. This limited goal is also in-line with a recent speech given by the NDRC at a People's Republic of China EV Conference. The speaker stated: "The State Council doesn't want to regulate EV production capacity; that should be left to the market…rather we expect major auto makers to get fully prepared in EV technologies by 2011 and come up with EV specification standards."[39] This statement clearly indicates that the

[35] National Development and Reform Commission (NRDC) People's Republic of China website. http://en.ndrc.gov.cn/

[36] Transition to hydrogen-based transportation in China: Lessons learned from alternative fuel vehicle programs in the United States and China Energy Policy Volume 34, Issue 11, July 2006, Pages 1299-1309 Hydrogen.

[37] Ibid.

[38] Yu Dawei, "China Should Speed Up New-Energy Vehicle Development," *Caijing,* April 28, 2009. http://english.caijing.com.cn/2009-04-28/110155209.html

[39]工信部主持召开了规格极高的"2009中国电动汽车产业发展国际论坛"期间，日产与工信部和武汉市政府签署了两项协议书，包括为工信部制定包括充电网络建设和维护，促进电动车大规模使用的综合规划，同时在2011年在武汉首先推出电动车

Chinese government is not focused on directing production resources to the EV industry, but rather is taking a "wait-and-see" attitude towards EV technological and manufacturing development. As a result, the large scale subsidies and necessary infrastructure upgrades that are necessary for near-term EV adoption in China will not be forthcoming.

ASSESSING THE ROLE OF ACTIVISTS IN EV ADOPTION

"Activism" Redefined in the Chinese Context

While the Chinese government is apprehensive about allocating resources to EV adoption, it is possible that "activist" entities within the political economy can push the government into action. In the U.S. and Europe, activists are characterized by non-market actors, such as NGOs, lobbyists, consumer groups and associations.[40] In China's one-party political economy, this definition is stale. Chinese laws require the registration of all organizations with the government and rules forbid the public gathering of large groups of people – making it difficult for non-market actors to exert influence over government and corporations.[41] Given the Chinese context, a more appropriate definition of the term "activist" would focus not on non-market actors that influence the government as a whole or corporations, but rather on those entities that can influence the NDRC.

Government Ministries as Activists

Setting aside corporations, the two key activist organizations affecting the adoption of EVs within China are the Ministry of Industry and Information Technology (MIIT) and Ministry of Science and Technology (MOST). While MOST is focused on directing R&D efforts, MIIT is dedicated to regulating and developing major industries. MOST was founded in 1998 and has been involved in directing Chinese battery R&D efforts since its inception.[42] MIIT is a recently formed ministry (2008) that is responsible for regulation and development of major industries, including the automobile industry.[43] Once the EV manufacturing supply chain matures, it is slotted to fall under MIIT's supervision as well.[44] Since battery technology is critical to the development of EVs, the two ministries have been competing for leadership in defining EV R&D and regulation – an area of potential future national interest and funding.[45]

Evidence of this competition has emerged in 2009. In April 2009, for example, MIIT – despite its mandate to only focus on major industries – hosted a global forum exclusively dedicated to setting standards for future EV development.[46] The forum was considered a milestone for the EV industry, since it set the tone for the future growth of the industry as a potential major player

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40 "What is an Activist," http://www.activistrights.org.au/cb_pages/what_activist.php
41 The Central People's Government of the People's Republic of China website. http://www.gov.cn/flfg/2005-08/05/content_20965.htm
42 http://news.sohu.com/20090907/n266519740.shtml
43 "PRC Government Structure Report. http://www.uschina.org/public/china/govstructure/govstructure_part5/12.html
44 http://info.auto.hc360.com/2008/07/091445291562.shtml
45 http://www.yangtse.com/sytj/syqc/200907/t20090714_670621.htm
46 Ibid.

in the Chinese market.[47] From this forum, Nissan (and the DongFeng Nissan JV) emerged the winner in this critical first round of EV standard-setting in China. Furthermore, Nissan was named the exclusive strategic partner in a memorandum of understanding between MIIT.

MIIT's patronage of Nissan is a clear effort to lay-out a series of standards, which will define the status quo in advance of any NDRC decision-making. This standard-setting is also an evident play to wrest influence away from MOST. It is worthy of note that the prominent battery manufacturer, BYD, which falls under MOST's supervision was not even invited to the forum.[48] Nevertheless, MIIT took the opportunity to classify BYD's Li-on battery technology as "intermediate phase", while classifying Nissan's battery technology as "mature phase". Again, the implications of this early "phase" standard-setting has tremendous implications for defining the development of EVs in China and the status quo that the NDRC will have to work within. EVs with "intermediate phase" batteries can only be sold to 14 "test" cities in China in small scale. Meanwhile, Nissan's exclusively designated "mature phase" battery technology can be sold with EVs anywhere in the Chinese market. [49]

MIIT's actions on behalf of Nissan and the automobile industry may lie in the heritage of MIIT leadership. The former chairman of the DongFeng Nissan JV, Yu Miao is currently the vice minister of MIIT. Mr. Yu, is far more than a vice minister – he is a business celebrity who garners greater name recognition than BYD's CEO Wang Chuanfu. Mr. Yu created JVs with Honda and Nissan, and pioneered quality automobile mass production in China.[50] As a result, it would not be surprising to continue to see MIIT favoring players in the automotive industry in driving EV adoption and standard setting in advance of any specific decision-making at the NDRC level.

The Local Government as Activist

As with government ministries, local governments can play a role pushing forward policies that define the status quo and force the NDRC's hand in supporting the adoption of the EV. While MIIT advocates for China's automobile producers, BYD has a strong ally in the city of Shenzhen. Indeed, BYD is headquartered in Shenzhen, which was the first city to open-up to the world during the 1978 reforms and currently has the highest per-capital GDP of any city in China.[51] Shenzhen's political influence should not be underestimated since its economic power is that of several provinces combined. With the possibility of BYD building a "Detroit" for the EV market in Shenzhen, the municipal government has lobbied the NDRC to cast favor on the company.[52]

Thus far, the Shenzhen government has not only provided BYD with a test market in the government's vehicle fleet, but the municipality has also established a strategic partnership with

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[47] Ibid.
[48] Ibid.
[49] http://www.yangtse.com/sytj/syqc/200907/t20090714_670621.htm
[50]http://auto.sina.com.cn/z/drltreaty/index.shtml
[51] "Shenzhen," Wikipedia website.
http://en.wikipedia.org/wiki/Shenzhen
[52] http://blog.qq.com/qzone/622007689/1229357735.htm

the China Development Bank on behalf of BYD. This partnership is significant because the China Development Bank is the investment bank representing central government and it arranges investments in major SOEs and infrastructure. It is crucial to recognize that the last time the Shenzhen municipal government established this type of partnership it was with Huawei – a local start-up which became the second largest telecommunication manufacturer in world.[53] Hence, Shenzhen is positioning BYD to receive favor from the NDRC as it determines funding and development of the EV in China.

Activists Opposing the Adoption of EVs

While MIIT, MOST and certain local governments seek to promote EV adoption, powerful activists exist within the Chinese political economy that seek to block the adoption of EVs. The overlapping responsibilities between ministries, local governments and corporations create a dynamic where uncertainty over responsibilities produces a power vacuum for large entities to exert control. One such area is the energy sector. As a result, the state-owned energy companies represent powerful autonomous actors who are well-represented in ministries, the NDRC and other organs of influence within the Chinese Communist Party.[54]

Unfortunately for proponents of the EV, utilities and oil companies have stated little interest in widespread EV adoption. Major Chinese oil companies are not interested in seeing a key source of revenue threatened – PetroChina and Sinopec derive 47 percent and 34 percent of their sales from gas and diesel.[55] While utilities may benefit from increased demand for power, they have shown little motivation to make the investments to upgrade their plant and provisioning technologies for EVs. A central reason for this behavior is that utilities are evaluated by the government on reliability. Given the lack of government interest in inducing the EV effort as a whole, utilities have been reluctant to initiate the large and complex investments necessary to support widespread EV adoption.[56] Hence, the oil and utility industries are two powerful agents in the political economy that seek to block or to slow the adoption of EVs in China.

Within the Chinese political economy, the strongest forces of activism on the NDRC are seen in large state-owned enterprises, the ministries and the local governments. While MIIT can set standards that will affect adoption, local governments can bring tremendous economic resources to bear in order to push a given company into a position of favor with the NDRC. Meanwhile, large state-owned enterprises with direct membership in NDRC decision-making can divert government resources away from inducing EV adoption. Looking strictly at the activists forces, the future outcome of the EV market is unclear at the present time.

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[53] http://sjoem.com/news/news-53032.html
[54] Erica S. Downs, "China's 'New' Energy Administration: China's National Energy Administration Will Struggle to Manage the Energy Sector Effectively," *China Business Review,* November-December 2008.
[55] Petrochina 2008 Annual Report
http://www.petrochina.com.cn/resource/EngPdf/xwygg/ew_20090415_annual_report.pdf;
http://english.sinopec.com/download_center/reports/2007/20080406/download/AnnualReport2008.pdf
[56] Erica S. Downs, loc. cit.

IF NOT INDUCED – THEN AUTONOMOUS?
CROSS-BOUNDARY DISRUPTION POTENTIAL IN THE CHINESE EV MARKET

While MIIT has stated its support of Nissan over BYD as the frontrunner of China's EV industry, the local efforts of the Shenzhen government to support the battery manufacturer BYD cannot be ignored. A closer look at the political and economic dynamics suggests that conditions are ripe for BYD to become a cross-boundary disruptor in EV automobile manufacturing. In examining BYD's potential as a cross-boundary disruptor, it is necessary to assess seven conditions set out by Burgelman and Grove.[57] These conditions are outlined below:

External Industry-Level Conditions

- Is the industry in decline?
- Is there a large market opportunity?
- Is there a confluence of market and non-market forces

Internal Company-Level Conditions

- Does the company possess a culture of innovation?
- Is the company resource rich?
- Is the company hungry for growth?
- Does the company possess bold leadership?

External Industry-Level Conditions
Innovation stasis in the automotive industry

Since Henry Ford's introduction of the Model T car at the beginning of the 20th century and the mass adoption of the internal combustion engine passenger car that followed, there have been very few revolutionary concepts that have been introduced successfully to the marketplace. With gradual consolidation, the top five players in the world automotive industry (Toyota, GM, Volkswagen, Ford and Honda) manufactured over 40 percent of all passenger cars in 2008.[58] While these industry players have dabbled in alternative vehicles, other than Toyota's success with the Prius, to date, none have managed to successfully transfer their plug-in or full electric vehicle technology from their R&D labs to the marketplace. Given that sales of traditional ICE cars are still strong and growing, and that auto manufacturing processes have been optimized to produce such cars, these incumbent players have had little incentive to convert their operations entirely to produce a revolutionary type of alternative energy vehicle. This has opened up the opportunity for startups such as Tesla Motors, not burdened with existing infrastructure, to leapfrog these incumbents, attempt to overcome the overwhelming minimum efficient scale associated with auto manufacturing, and produce a viable full electric vehicle.

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[57] Robert A. Burgelman and Andrew S. Grove. "Cross-Boundary Disruptors: Power Inter-Industry Entrepreneurial Change Agents," *Strategic Entrepreneurship Journal,* October 2007.

[58] World Motor Vehicle Production 2008.
http://oica.net/wp-content/uploads/world-ranking-2008.pdf

Market Opportunity for Battery Manufacturers

In 2008, 69.5 million vehicles were produced. Of these, 55.8 million are cars (the remaining vehicles are light and heavy commercial vehicles and buses).[59] Consider the extreme scenario in which all 60 million cars are full electric Tesla Roadsters, each requiring 6831 commodity-grade lithium-ion batteries currently available.[60] This would require over 400 billion batteries. Compare this to the 2008 demand for lithium-ion batteries worldwide at 3.5 billion.[61] Even a 10 percent conversion of the world auto production to electric vehicles would increase the demand for existing commodity batteries several-fold. Without considering improvements in battery technology and fixing prices, a straightforward increase in demand volume is a boon to battery manufacturers worldwide.

Confluence of Non-Market Forces – National Policy, Batteries, EVs and Employment

The Chinese battery industry is of strategic national importance because of its potential for growth and differentiation. China has plateaued as the dominant world exporter of commodities such as footwear and apparel.[62] Given this market position, central and local governments are likely actively seeking opportunities to produce high value-added products that leverage their manufacturing bases and employ their labor markets. Indeed, from this perspective, batteries are an attractive product for manufacture because their production can be both capital and labor intensive.[63]

Not surprisingly, China is becoming an increasingly important global production base for lithium-ion batteries. Not only does China dominate the world export share for batteries overall,[64] it is capturing the world export share faster than any other country.[65] In 2005, the value of China's total battery exports topped $4 billion, compared with less than $1 billion for the United States, and less than $3 billion for Japan.[66] Having surpassed Japan as the major

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[59] Ibid.

[60] Tesla Motors website. http://www.teslamotors.com/blog2/?cat=19

[61] China Business Intelligence website. http://www.researchinchina.com/Htmls/Report/2009/5686.html

[62] International Cluster Competitiveness Project, Institute for Strategy and Competitiveness, Harvard Business School, *https://secure.hbs.edu/iccp/index.jsp*.

[63] Robert S. Huckman and Alan MacCormack, "BYD Company, Ltd." Harvard Business School Case, April 2, 2006.

[64] Source: International Cluster Competitiveness Project, Institute for Strategy and Competitiveness, Harvard Business School. Lighting and electric equipment cluster (battery subcluster).

[65] Source: International Cluster Competitiveness Project, Institute for Strategy and Competitiveness, Harvard Business School. Lighting and electric equipment cluster (battery subcluster).

[66] Source: International Cluster Competitiveness Project, Institute for Strategy and Competitiveness, Harvard Business School. Lighting and electric equipment cluster (battery subcluster).

producer of lithium-ion batteries in 2007,[67] China produced 1.5 billion of the 3.5 billion lithium-ion batteries demanded by the global markets in 2008.[68]

Home to major lithium-ion battery manufacturers BYD, BAK and B&K, Shenzhen produced 70 percent of all of the lithium-ion units produced in China with the majority of units produced by BYD.[69] While there are over a hundred lithium-ion battery companies in China, BYD is clearly the largest player in China and has become the dominant player by supplying consumer electronics and mobile phone manufacturers such as Apple and Nokia with battery units.[70] Hence, in examining the potential for the Chinese battery manufacturing industry to produce a cross-boundary disruption, it is only meaningful to consider BYD as a potential disruptor.

Confluence of Non-Market Forces- City of Shenzhen: Complementary goals

Shenzhen was China's first special economic zone and continues to be a hub for high-tech manufacturing and innovation. The city ranks first in foreign trade volume and, coupled with the local absence of incumbent traditional auto manufacturers, Shenzhen provides an ideal hotspot for the development of an electric vehicle manufacturing base.[71] In addition, Shenzhen's local government has already provided a combination of generous subsidies and EV pilot programs.[72] Indeed, with 130,000 workers, a highly desirable portfolio of high-tech products and a rapidly growing presence on the world stage after Warren Buffett's purchase of 10 percent of the company, BYD is one of Shenzhen's crown jewels.[73] While BYD may not have the stated support of the central government, it is arguable that the support of a strong regional government with aligned interests is enough and perhaps more nimble than lobbying politicians in Beijing.

Confluence of Market Forces – EV batteries: Two divergent development strategies

Two strategies have emerged in reducing the range and power-to-weight ratios for EV batteries. The first strategy is to invent, develop and successfully manufacture, in high volume, a very high power-density battery specifically for EV use. The second is to develop and manufacture an integration system that employs commodity lithium-ion battery technology used in consumer electronics – as Tesla Motors has done.[74] Both of these strategies are complementary to BYD's core capabilities. BYD has a competitive advantage with respect to the former strategy as it has the R&D and process engineering capability to systematically explore and prototype disruptive

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[67] "China Surpasses Japan as World's Largest Lithium-ion Battery Maker," *EV World,* July 29, 2008. http://www.evworld.com/news.cfm?newsid=18789

[68] China Li-ion Battery and Its Raw Materials Market Report, 2008-2009, China Business Intelligence website http://www.researchinchina.com/Htmls/Report/2009/5686.html

[69] Rough estimate based on total output of China and sum of outputs from BYD, BAK and B&K.

[70] BYD Annual Report 2008. http://www.bydit.com/doce/investor/notify_show.asp?year=2008&sort=Annual%20Report

[71] Shenzhen Government Online. http://english.sz.gov.cn/economy/200911/t20091120_1229164.htm.

[72] Wang Zhen, "Shenzhen plans subsidy for hybrid cars," Caijing, June 16, 2009. http://autos.globaltimes.cn/china/2009-06/437233.html

[73] Marc Gunther, "Warren Buffett Takes Charge," *CNN Money,* April 13, 2009. http://money.cnn.com/2009/04/13/technology/gunther_electric.fortune/

[74] Tesla Motors Company website. http://www.teslamotors.com.

battery technology.[75] BYD also gains with respect to the latter strategy as it currently holds 30 percent of the lithium-ion battery market.[76] Given these two complementarities, the electric vehicle serves as a strategic channel through which BYD can focus its existing capabilities to capture new markets.

Internal company-level conditions

In addition to satisfying the external industry level conditions for a cross-boundary disruptor, BYD's internal company-level conditions also meet the criteria.

- **Culture of innovation:** BYD has a culture of entrepreneurship and innovation. Lacking the capital normally required to start a battery manufacturing firm, BYD invented new battery chemicals that are less sensitive to humidity which eliminated the need for a costly humidity-controlled environment, and developed new processes to optimize the manufacturing of batteries via manual labor. Compared to its competitors, BYD continues to invest disproportionately (3 percent of revenues) in product and process R&D to this day.[77]

- **Resource Rich:** Flush with a capital infusion from the equity markets in 2009, BYD is well positioned to rapidly accelerate its development and manufacturing of electric vehicles. BYD has experienced double digit growth in revenues and net profits for the past few years, decelerating only slightly in the past year due to the recession[78] (See **Exhibit 1**).

- **Hungry for growth:** While BYD still has room to grow its lithium-ion battery business in the consumer electronics market, cell phone and laptop batteries have been largely commoditized and the industry is saturated. To maintain its current pace of growth, BYD must stoke the demand for its commodity products to grow its manufacturing and sales volume as margins wither, while developing a market for premium products in its pipeline.

- B**old Leadership:** Wang Chuan Fu, the man at the helm, has publicly stated his desire and commitment to conquer the world. Behind the scenes, he has established a culture of healthy debate and questioning, which is extremely rare and unique for a Chinese company.[79] The same confidence and ambition that led Mr. Wang and BYD to the number one spot in batteries in less than a decade will propel them to overcome their weaknesses (e.g. lack of B2C sales and marketing capabilities) and tackle the electric vehicle industry.

BYD clearly has the potential to play the role of a cross-boundary disruptor in the Chinese EV market. With respect to the propagation of industry change (See **Exhibit** 2), BYD's actions have

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[75] Robert S. Huckman and Alan MacCormack, "BYD Company, Ltd." Harvard Business School Case, April 2, 2006.

[76] BYD Annual Report 2008.
http://www.bydit.com/doce/investor/notify_show.asp?year=2008&sort=Annual%20Report

[77] Robert S. Huckman and Alan MacCormack, "BYD Company, Ltd." Harvard Business School Case, April 2, 2006.

[78] Marc Gunther, "Warren Buffett Takes Charge," *CNN Money,* April 13, 2009.
http://money.cnn.com/2009/04/13/technology/gunther_electric.fortune

[79] Based on personal experiences. Phone interview with Liam Casey, CEO of PCH International.

already impacted the automobile industry by generating media excitement and increasing consumer awareness worldwide. However, whether or not BYD becomes the dominant player in the global market is yet to be seen. Given the price point of its cars ($40,000 USD for the E6 is beyond reach for most Chinese consumers, even middle-income Shenzhen residents) and the external conditions it faces in its home market, BYD is much more likely to succeed first in providing batteries for export EV markets and then in penetrating its home market with its batteries and its EVs.

Conclusions on the Near-term Dynamics of EV Adoption

After evaluating induced government policies, the efforts of activists and the potential for cross-boundary disruptors, the near-term prospects for EV adoption in China look dim. The strong government spending and incentives that have been responsible for China's infrastructure growth and electrification are completely lacking in the case of EVs. Meanwhile, the efforts of activists are conflicting and self-defeating, which makes them unlikely to be able to focus the resources of the NDRC. Finally, while BYD presents a viable XBD candidate, the company still lacks the cost-effective battery technology to disrupt the automotive industry at the present time.

Assessing the Future of EV Adoption – 3 Scenarios

Evaluating the future of EV adoption is fraught with uncertainty. In order to mitigate this variance and draw insight, the following discussion pursues a methodological approach. Assessing the future requires three steps.

1) The first step is to define what "future" really means. For the purposes of this analysis – "the future" refers to 2020, or ten years from now.

2) The second step is to identify the key factors that affect the scaling of EV technology. There are four factors that affect EV adoption:
    - **Oil price:** The oil price affects the relative cost of ownership of EV and ICE vehicles and therefore the demand and scaling of EV adoption.
    - **International commitment to addressing climate change:** The international commitment to addressing climate change could create demand for EVs outside of China and thereby create large scale production benefits in the Chinese auto and battery manufacturing industry.
    - **Pace of battery technology advancement:** The cost of a battery with a given power density also affects the relative cost of ownership of EV and ICE vehicles.
    - **Chinese political commitment to addressing environmental issues:** China's level of political commitment to address local and global environmental issues will affect both the relative cost of ownership of EV and ICE vehicles through subsidies as well as the restructuring of the power dynamic between the oil, energy and automotive industries.

3) The third step is to create future scenarios that vary the key factors and draw insights from the implications of each scenario. In order to construct and analyze these scenarios,

we built ground-up projections, drew on third-party data sources, relied on expert interviews and used a regression analysis of a data set of Chinese consumer surveys to estimate demand for vehicles at various price points.

Finally, before beginning the scenario analysis, it is worthy of note that we maintained certain "states of the world" constant throughout each of the following analyses. These are:

1) National security and energy security are always a top priority for the Chinese government
2) Social stability and employment are also a top priority for the Chinese government
3) $3,000 vehicles are commercialized for the developing world starting in 2010

Scenario #1: "Coal's (Middle) Kingdom"

Key Variables:

- Oil price: **$75/barrel**
- International commitment to addressing climate change**: Low**
- Pace of battery technology advancement: **Low**
- Level of national Chinese political commitment to addressing environmental issues: **Low**

Narrative

In Scenario #1, global geopolitical relationships sour – the downturn of 2008 and a failure to reach a global post-Kyoto agreement on climate change breed disillusionment and mistrust. To meet growing energy needs, the U.S., China, and other oil importers scramble to strengthen relationships with country's holding the world's remaining oil reserves while aggressively developing coal-to-liquid technology and exploiting tar sands and oil shale. Through the development of intensive 'dirty' liquid fuels, oil prices remain near $75/barrel through 2020. Short-sightedness and volatility in oil prices leads to limited investment in "clean" technologies, including EVs. The $3,000 automobile takes off in China, largely fueled by advanced coal-to-liquid fuels by Shenhua Coal and other state-owned enterprises (SOEs). The flooding of these new vehicles onto the road—along with the coal refineries to create more fuel—intensify environmental degradation while clogging cities with traffic. From the government's perspective, however, the new employment created by China's auto industry and the convenience to drivers ultimately outweighs the air quality concerns. There is no meaningful induced strategy from the Chinese government, while BYD and other battery manufacturers find incremental improvements to existing battery technologies at the historical 8 percent rate, but generate no significant break-throughs.

Implications for EV Costs

With neither induced nor autonomous change taking place in Chinese markets or abroad, the EV manufacturing supply chain does not scale up. We arrive at this conclusion by building a model comparing the relative ownership costs of HEV, PHEV, EV and ICE vehicles. The model is constructed under certain key assumptions – they are described below:

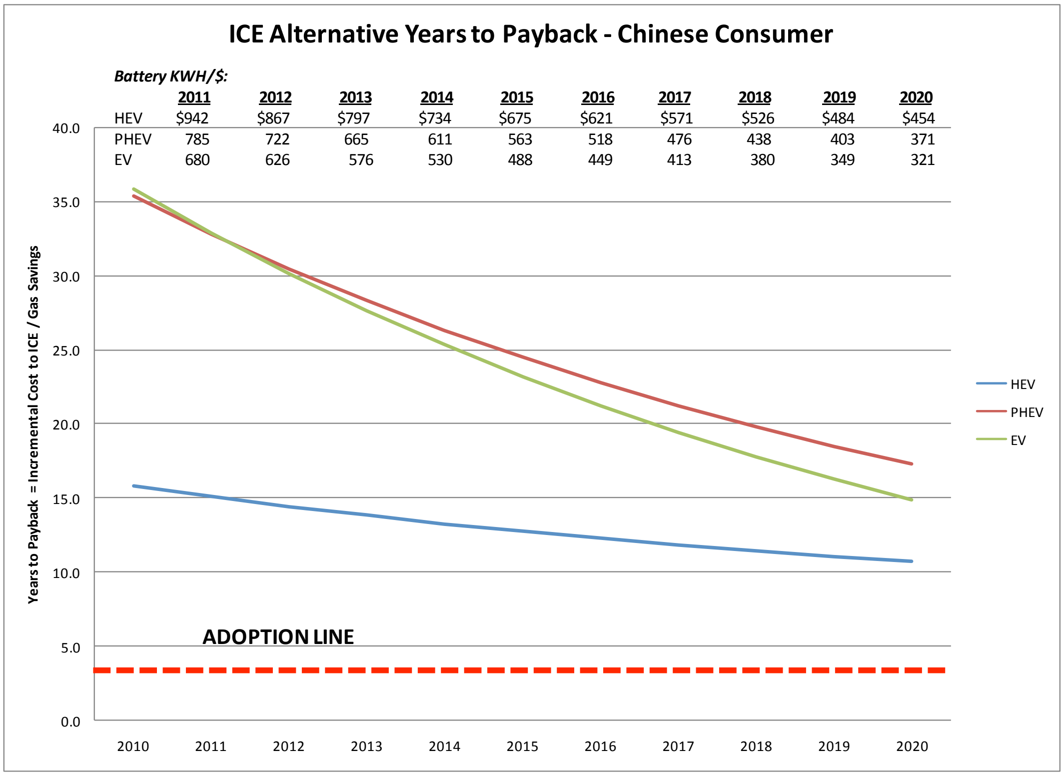
- Within China, existing displacement-based taxes on ICE vehicles provide a modest savings for vehicles using electric technology - $600 for EVs and $300 for HEV and PHEV

- 7,500 miles annual driving range for Chinese consumers (half of the US average due to prevalence of urban driving[80]
- 15,000 miles annual driving range for US consumers
- 33MPG for ICE, 49 MPG for HEV
- $.1/kWh and 4 miles/kWh for EV
- PHEV drives 1/3 in gasoline mode and 2/3 in electric mode
- HEV, PHEV, EVs are assumed to use different electric drive trains, which require batteries with different costs[81]
- Existing battery technology improves at a rate of 8% per year (i.e. equal power density for lower cost)[82]
- Consumers begin to adopt alternatives to ICE vehicles if the payback period (incremental cost above ICE/annual gas savings) is less than 3 years
- An example of the detailed cost calculations can be seen in **Exhibit 3**

The followingchart represents the payback period of a vehicle purchased in a given year for each type of electric vehicle technology. If a particular type of vehicle gains a payback period of less than 3 years, then consumers will view it as practically "cheaper" than an ICE vehicle and will adopt it en masse. This 3 year adoption threshold is labeled on the chart with a red line titled – "Adoption Line." As a reminder, the lines are downward sloping because battery technology improves incrementally every year at the historical rate of 8 percent. The assumed battery prices per kWh are listed across the top of the chart. Please note that these prices should be useful to a reader who may not believe our battery price assumptions. Such a reader can identify the price they find realistic and look to see whether adoption occurs at this price level.

[80] "British drivers on brink of breakdown," Direct Line press release. http://www.directline.com/about_us/news_300605.htm
[81] "Great Leap Forward or Déjà vu? The alternative energy car landscape for China in 2020,"AT Kearney, 2009.
[82] Based on a visit to Tesla Motors.

Implications for EV adoption in China



Source: Created by research paper authors.

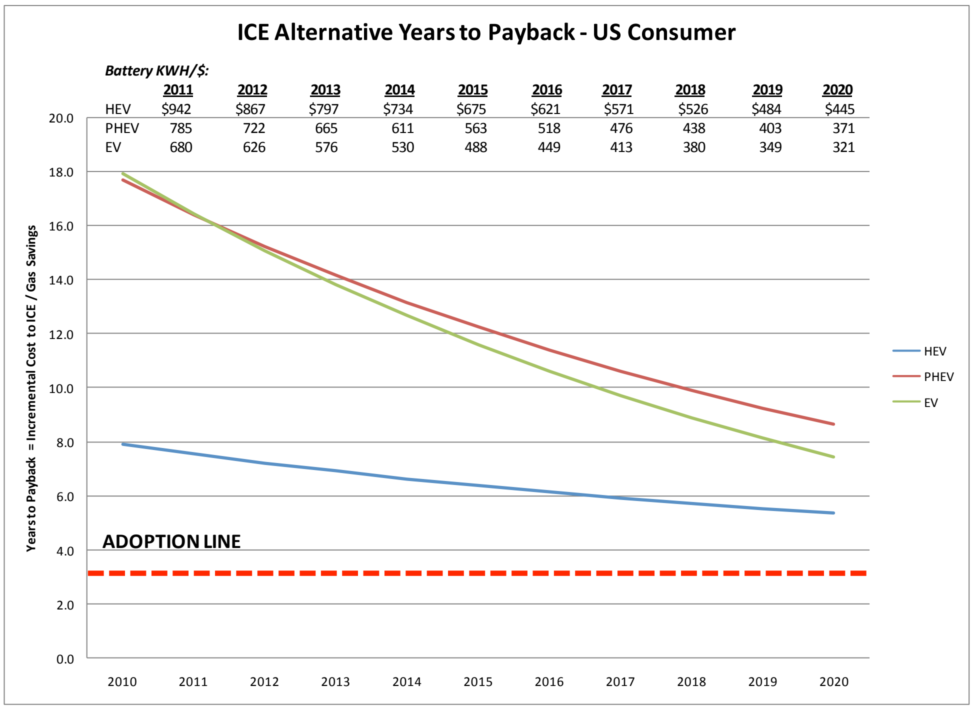
Given the high costs and modest government incentives, the model suggests that the EV adoption rate will be stagnant in Scenario #1. As a result, it is assumed that EV sales remain at the current level of 0.1% of total sales.[83] Using a Deutsche Bank projection on total Chinese car sales, we estimated the EV adoption under this scenario as follows:

China EV Adoption in Scenario #1 (000 units)

	2009E	2015E[84]	2020E
EV	10.0	15.8	19.0
Total Auto Sales	9,651	15,828	19,000

[83] "Electric Cars Plugged-in 2," Deutsche Bank, page 32, 2009.
[84] We took 5 year incremental because the design cycle of cars is 5 years.

Implications for EV Exports to the US:



Source: Created by research paper authors.

Given lower oil prices and a waning global commitment to climate change, we expect global EV sales to be very low overall, since adoption does not make economic sense for consumers. High EV penetration would be limited to smaller markets, with strong government interests in stimulating adoption, such as in Israel and Denmark. In conclusion, in the absence of induced and autonomous forces pushing for EV adoption, the EV production supply chain in China does not scale up.

Scenario #2: "EVs for the World (Not for China)"

Key Variables:

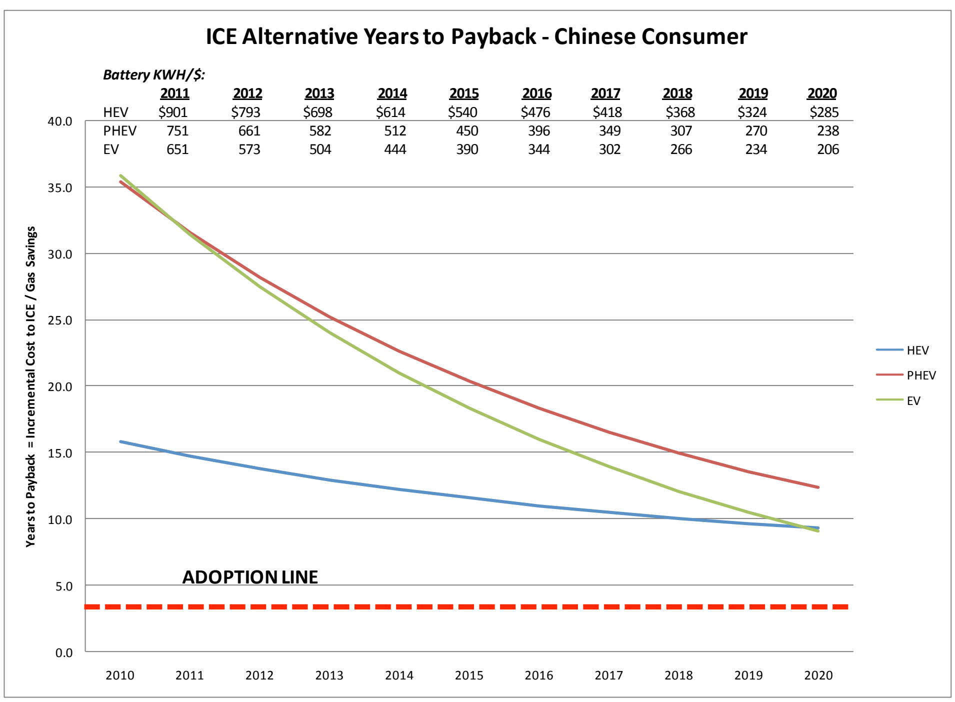
- Oil price: **$75/barrel**
- International commitment to addressing climate change**: High**
- Pace of battery technology advancement: **Moderate**
- Level of national Chinese political commitment to addressing environmental issues: **Low**

Narrative:

A global agreement on climate change is reached, which includes strong incentives for technology transfer and trade penalties for violation. While the treaty spurs adoption of clean energy technologies in the developed world, China was able to negotiate weak targets as a developing nation; moreover, given cars make up less than 5 percent of China's greenhouse gas emissions, China's post-Kyoto strategy relies heavily on hydroelectric and nuclear power—an extension of its early green stimulus investments. Though the Chinese government maintains its focus on growth over green, Chinese entrepreneurs such as BYD see an opportunity in battery and EV component manufacturing, pursuing export-led manufacturing of electric vehicles batteries; the $3,000 car gives China an 'in' into foreign markets, which OEMs eventually leverage to export their own fully-integrated EVs. As the US shifts to EVs, EV production for export in China scales up and costs to consumers fall.

Implications for EV Costs:

The same cost assumptions used in Scenario #1 are applied to Scenario #2. However, due to incentives to adopt low-carbon vehicles in the US, battery costs are driven down by economies of scale and the learning curve. Specifically, battery prices decline at a rate of 12 percent annually, or 50 percent faster than the historical average. The low level of national Chinese political commitment is reflected in the continued absence of consumer subsidies for purchases of cars with electric technologies. The results of this scenario in China are in the following figure:



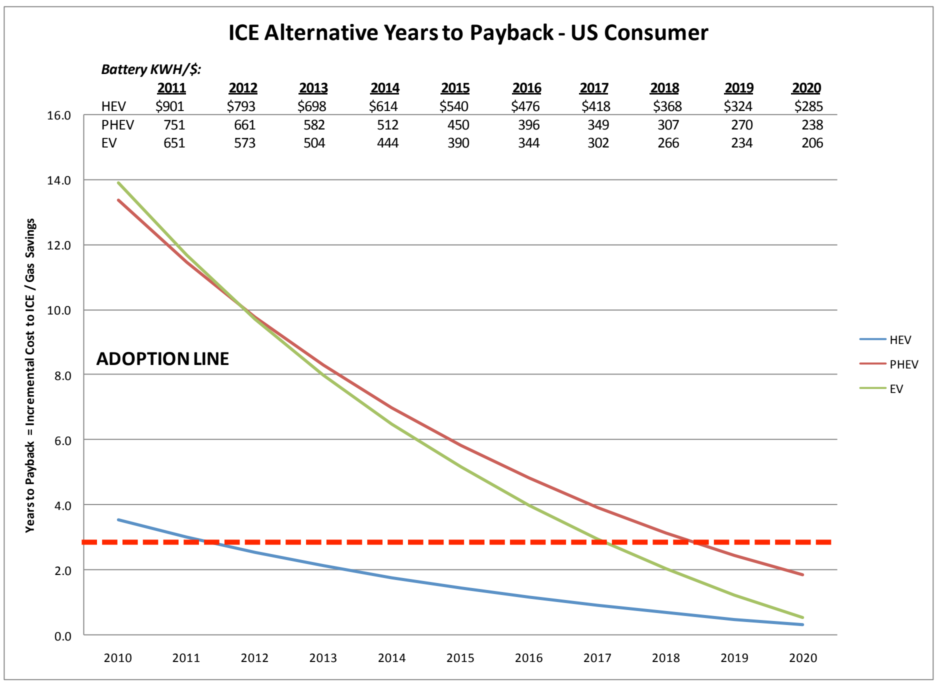
Source: Created by research paper authors.

Implications for EV Adoption in China

As in Scenario #1, we see in Scenario #2 that the relative payback period to Chinese consumers is too high to make mass adoption of EVs a reality. Even if rapid efficiency gains are made, the electric technology vehicles do not make economic sense. A key driver of this conclusion is that Chinese people make lower utilization of their cars than in the US (or rather, utilize their cars more closely to urban societies such as those found in Europe) that may allow the Chinese EV production industry to scale. As a result, the ability to generate gas mileage savings is more limited. The only policy solutions to this challenge are to further reduce the relative upfront cost of EVs through subsidies or to fund R&D to improve battery technology at an even faster rate.

As in Scenario #1, Scenario #2 results in an insignificant market share for electric technology vehicles in China through 2020.

Implications for EV Exports to the US:
In this scenario, the US steps up subsidies for electric vehicles as it becomes more concerned with climate change and environmental issues. The cost model assumes a $2,000 subsidy for HEV, $3,000 subsidy for PHEV and a $4,000 subsidy for EVs. The results of these adjustments are in the following figure.



Source: Created by research paper authors.

As one might expect, the addition of subsidies and the increased vehicle utilization bring the payback periods into attractive territory for US consumers. So while, adoption in the Chinese market may be low, the conditions in Scenario #2 – moderate battery innovation and favorable policy abroad – are sufficient to create a meaningful export market for EV batteries (and perhaps its cars). As a final observation, according to our model, the large scale adoption of EVs in Chinese export markets would only occur right before 2020 and not in the immediate future.

Scenario 3: "China – The EV Nation"
Key Variables:

- Oil price: **$150/barrel**

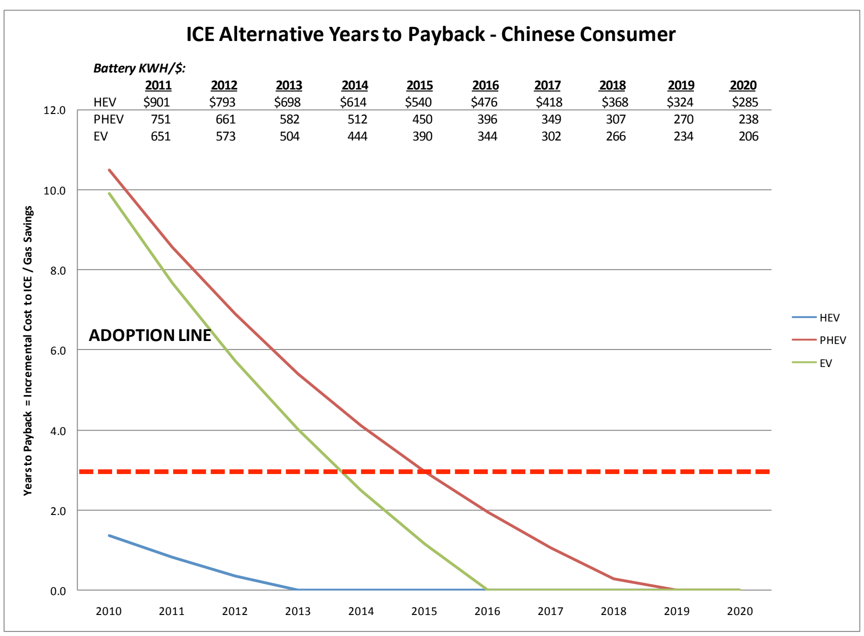
- International commitment to addressing climate change: **High**
- Pace of battery technology advancement: **Moderate**
- Level of national Chinese political commitment to addressing environmental issues: **High**

Narrative

A confluence of high oil prices, energy security concerns, local air pollution concerns, and economic opportunity in the auto sector drive Chinese government to aggressively induce EV development. Early local adoption of EVs is encouraged through subsidies to 'leap frog' the oil-dependent transportation sector. The US government props up and steers incumbent auto players and entrepreneurs to build high-quality EVs With a strong manufacturing base and heavy R&D in Li-ion technology, China becomes a leader in EV manufacturing and in surmounting the challenges of deploying them locally. This positions China as a significant exporter of EVs, first through JVs with companies like Nissan, but eventually of domestic brands, as well. In many ways, China's EV sector shows parallels to the Danish wind sector—by growing strong at home, it was well positioned to enter the global market.

Implications for EV Costs

Scenario #3 uses the same base cost assumptions and 12 percent battery innovation assumption as Scenario #2. In addition, the energy crisis has doubled the price of oil for Chinese consumers. Finally, both the US and Chinese governments extend subsidies to consumers of $3,000 for HEV, $5,000 for PHEVs and $8,000 for EVs. The resulting payback decision curves for Chinese consumers are in the following figure.



Source: Created by research paper authors.

Implications for Chinese EV Adoption

The EV Nation scenario effectively removes the barriers to EV adoption that existed in Scenario #2. Higher gas prices and consumer subsidies resolve the issue of lower vehicle utilization in the Chinese context. It is worthy of note that HEV adoption occurs in the immediate future and EV adoption would not occur at a large scale in China until 2015.

The payback cost curves have helped determine whether EVs would be adopted or not. Now, in order to make a further assessment of the level of EV adoption in China, we used a series of market surveys by AT KEARNY to calculate consumer preferences for vehicles in China. We used the data from the customer surveys to create a regression model that predicts customer adoption at various price points. The model is described by the equation below:

Adoption Index = 71.0 – 2.0 * (Upfront Cost) - .45 * (Operating Cost) + 31.32 * ICE – 2.33 * EV – 17.1 * PHEV – 13.9 * HEV

The detailed statistical tables of this model can be found in **Exhibit 4**. For the purposes of this model, the variables ICE, EV, PHEV and HEV are categorical variables. We also incorporated the inexpensive ICE ($3,000) vehicles into the model. In order to integrate inexpensive ICE vehicles into our model, we considered two different markets - the inexpensive car market and the "regular" car market. In the inexpensive car market, we assumed that the upfront cost of an ICE vehicle would be $3,000. We also assumed that EV manufacturers would respond with an inexpensive EV with a reduced battery size. The cost of the inexpensive EV's is assumed to be $3,000 + the incremental cost of a regular EV over a regular ICE. In the regular car market, we assumed the ICE upfront cost was $15,000.

Entering the results of our cost analyses into the adoption model produced the following output.

	2015		2020	
	inexpensive car	regular car	inexpensive car	regular car
ICE	37.65%	48.19%	35.77%	43.18%
HEV	19.76%	16.17%	19.21%	15.22%
PHEV	17.46%	12.60%	18.93%	14.76%
EV	25.13%	23.04%	26.09%	26.84%

The output strongly suggests that there is a meaningful place for EVs and other electric technology vehicles in Scenario #3 despite the presence of low-cost ICEs. With the relative market shares of each type of vehicle in hand and using the assumption that two-thirds of Chinese vehicle sales will be inexpensive, we can map these figures against an estimate of the overall automobile market in China. The following table applies this methodology to a set of projections prepared by Deutsche Bank on the Chinese auto market.[85]

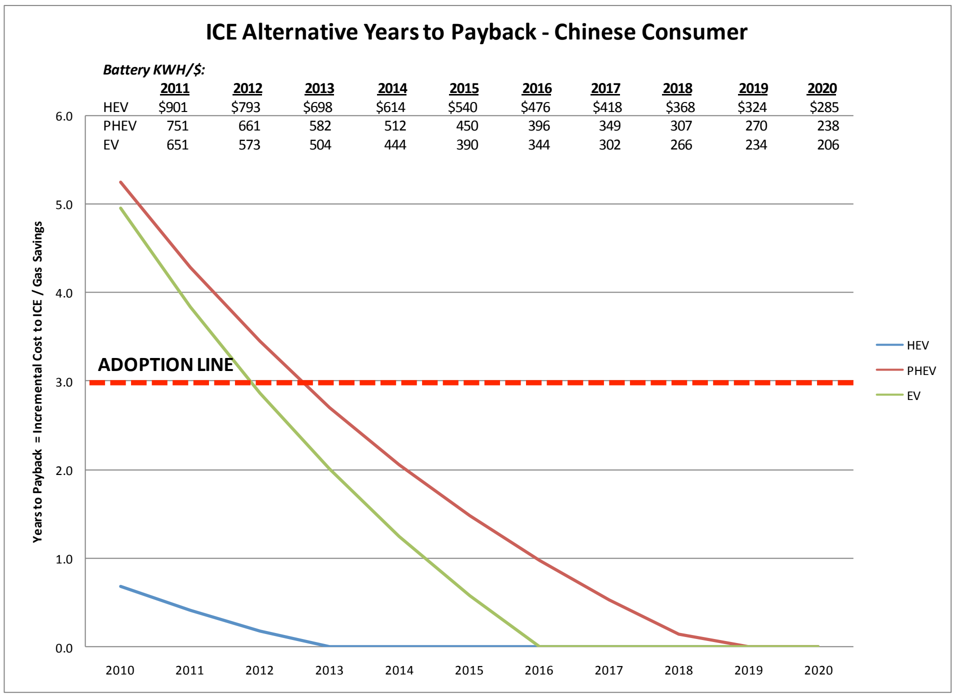
	2009E	**2015E**	**2020E**
EV (%)	0.1%	24.4%	26.3%
EV (000 Units)	10	3,867	5,004
Total Auto Sales	9,651	15,828	19,000

This methodology results in the expansion of annual Chinese EV sales into the millions of units. At an annual market size of 5 million vehicles per year (greater than Toyota's sales in the US

[85] "Electric Cars Plugged-in 2," Deutsche Bank, page 32, 2009.

market), there is potential for high scale manufacturing for a number of competitors in the Chinese EV arena. In short, there is a successful mass production and adoption of EVs in China.

Implications for EV Exports to the US
By developing a strong EV product domestically, China's should be able to develop and deploy a leading-edge vehicle and perfect the model domestically. Meanwhile, strong consumer incentives in the US coupled with high oil prices and vehicle utilization would result in widespread adoption of EVs and the potential for exports markets for China as is seen in the following payback analysis.



Source: Created by research paper authors.

CONCLUSION

In aggregate, the 3 scenarios yield a crucial insight: the necessary conditions for adoption are high vehicle utilization or $150 per barrel oil prices AND battery technological innovation at a 50 percent higher rate than the current one AND subsidies to consumers. This result suggests that the US and/or Chinese government must pursue an induced strategy in order to generate the scale of EV adoption necessary to make EVs a viable in product. It is beyond the scope of this paper to weigh-in on the probability that the US pursues a significant strategy to induce EV adoption by U.S. consumers. From the analysis of the Chinese market, however, it is clear that the government is interested in potentially participating in the battery export market, but is not motivated to expend resources to create a meaningful EV market internally. As the assessment of the transportation industry showed, this "wait-and-see" stance is justified, since emissions from automobiles are a tertiary concern for the Chinese government in the intermediate future. Hence, the scaling of the EV supply chain will depend on autonomous actors, such as BYD, finding a massive step-function innovation in battery power density or the US government providing its unbridled support for the industry.

Admittedly, our conclusion relies on China adopting a "wait-and-see" approach that delays EV adoption in the coming ten years, the potential exists for the Chinese government to shift policies during that the next 10 years – thereby rendering our conclusions incorrect. As a result, we thought it is useful to concluding our analysis with a series of "sign-posts" that serve as indicators that Chinese government policy is shifting and rapid EV adoption is imminent.

- The necessary task for EV adoption that requires the longest lead-time is reconciling the interests of the utility companies, oil companies and auto manufacturers. Government efforts to push these industries towards an agreement would indicate that a tectonic shift is in the making.
- A second task that is equally important, but requires less lead time is the implementation of meaningful subsidies for EV adoption. With the cost advantages of HEVs, these subsidies would need to be directed specifically at EVs in order to encourage scaled adoption.
- Finally, a third potential indicator would be for municipal governments to pass laws favoring EVs – these could take the form of bans on ICEs or increased licensing costs on ICEs.

These three sign posts are the key observed actions that would indicate a government policy shift toward supporting EV adoption. Without these actions, the efforts by foreign governments to push EV adoption and the ability of battery manufacturers to generate a technological paradigm shift will be central to forming a large scale EV production supply chain in China and creating widespread EV adoption in China.

Exhibit 1

BYD Company Limited. Key Statistics and Ratios

MARKET CAPITALIZATION

Market Capitalization	$154.14B
Share Price	$67.75
Shares	2.28B

Source: Google Finance. http://finance.google.com

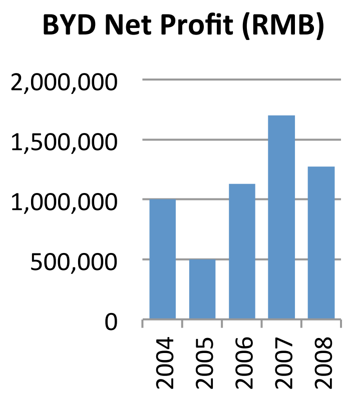
CONDENSED CONSOLIDATED FINANCIAL STATISTICS

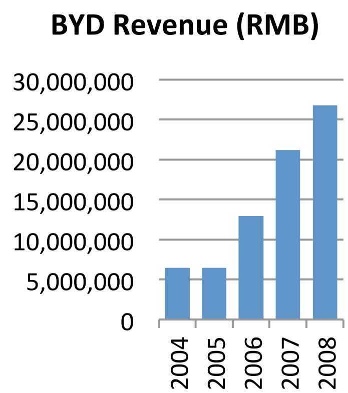
	FOR THE PERIOD ENDING		
	30 September '09 RMB '000	**30 September '08** RMB '000	**% Change**
Revenue	26,360,580	18,919,761	39%
Gross profit (for the period)	5,523,357	3,763,655	47%
Net profit (for the period)	2,554,033	991,818	158%
R&D Expenditure	783,139	849,147	-8%
Earnings per share	RMB 1.11	RMB 0.38	192%
Cash and cash equivalents (at end of period)	3,514, 996	1,800,777	95%

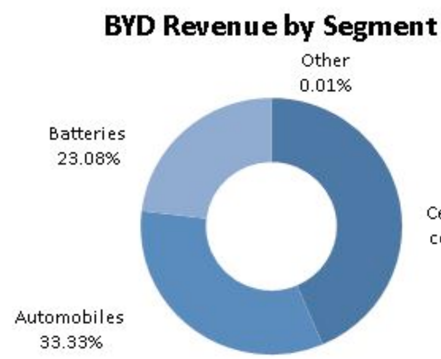
Source: BYD Unaudited Results for the Nine Months Ended 30 September 2006. Approved and posted on 26 November 2009. http://www.hkexnews.hk/listedco/listconews/sehk/20091126/LTN20091126519.pdf

Exhibit 1 (Continued)

BYD Company Limited. Key Statistics and Ratios

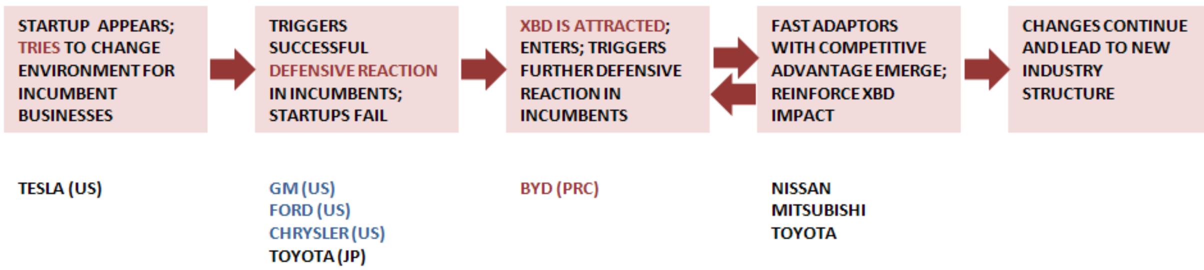






Source: BYD 2008 annual report.
http://www.byd-electronic.com/abu/files/20090421/20090421021430_1156.pdf

Exhibit 2
Cross Boundary Industry Change Propagation for the Global Electric Vehicle Industry



Source: Robert A. Burgelman and Andrew S. Grove, "Cross-Boundary Disruptors: Powerful Inter-Industry Entrepreneurial Change Agents," *Strategic Entrepreneurship Journal*, December 2007.

Exhibit 3
Cost Model Detail

Scenario #1

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HEV											
Battery $/KWH	1024	942	867	797	734	675	621	571	526	484	445
kWH	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Battery Cost	2048	1884	1734	1595	1467	1350	1242	1143	1051	967	890
Incremental Costs	1875	1875	1875	1875	1875	1875	1875	1875	1875	1875	1875
Tax on ICE Displacement	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300
Subsidy to Consumer	0	0	0	0	0	0	0	0	0	0	0
Total Incremental Costs	3623	3459	3309	3170	3042	2925	2817	2718	2626	2542	2465
Annual Fuel Savings	229	229	229	229	229	229	229	229	229	229	229
Total Payback Period (Years)	15.8	15.1	14.4	13.8	13.3	12.8	12.3	11.9	11.5	11.1	10.8
PHEV											
Battery $/KWH	853	785	722	665	611	563	518	476	438	403	371
kWH	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Battery Cost	11095	10207	9391	8640	7948	7313	6728	6189	5694	5239	4820
Incremental Costs	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Tax to ICE Displacement	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300
Subsidy to Consumer	0	0	0	0	0	0	0	0	0	0	0
Total Incremental Costs	12295	11407	10591	9840	9148	8513	7928	7389	6894	6439	6020
Annual Fuel Savings	347	347	347	347	347	347	347	347	347	347	347
Total Payback Period (Years)	35.4	32.9	30.5	28.4	26.4	24.5	22.8	21.3	19.9	18.6	17.3
EV											
Battery $/KWH	740	680	626	576	530	488	449	413	380	349	321
kWH	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Battery Cost	18492	17012	15651	14399	13247	12188	11213	10316	9490	8731	8033
Incremental Costs	0	0	0	0	0	0	0	0	0	0	0
Tax to ICE Displacement	-600	-600	-600	-600	-600	-600	-600	-600	-600	-600	-600
Subsidy to Consumer	0	0	0	0	0	0	0	0	0	0	0
Total Incremental Costs	17892	16412	15051	13799	12647	11588	10613	9716	8890	8131	7433
Annual Fuel Savings	499	499	499	499	499	499	499	499	499	499	499
Total Payback Period (Years)	35.9	32.9	30.2	27.7	25.3	23.2	21.3	19.5	17.8	16.3	14.9

Source: Created by research paper authors.

Exhibit 4
Statistical Output of Regression Model

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.889214909
R Square	0.790703154
Adjusted R Square	0.659892625
Standard Error	0.128393312
Observations	27

ANOVA

	df	SS	MS	F	Significance F
Regression	10	0.996450147	0.099645015	6.044644567	0.000803259
Residual	16	0.263757483	0.016484843		
Total	26	1.26020763			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.710459634	0.391646409	1.814033317	0.088469443	-0.119793658	1.540712927	-0.119793658	1.540712927
Upfront Cost	-0.021025422	0.013641721	-1.541258782	0.142797601	-0.049944578	0.007893734	-0.049944578	0.007893734
Operating Cost	-0.004538322	0.002626416	-1.727952841	0.103244177	-0.010106075	0.00102943	-0.010106075	0.00102943
CNG	-0.302405575	0.19386149	-1.559905351	0.138341336	-0.713373571	0.108562421	-0.713373571	0.108562421
M100	-0.308858652	0.199828928	-1.545615317	0.14174578	-0.732477054	0.114759749	-0.732477054	0.114759749
Gas	0.313252015	0.1938496	1.615953892	0.125648049	-0.097690776	0.724194805	-0.097690776	0.724194805
Diesel	-0.265106993	0.183849629	-1.441977307	0.168596865	-0.654850793	0.124636807	-0.654850793	0.124636807
Gas Hybrid	-0.13933753	0.185312208	-0.751906913	0.463025348	-0.53218186	0.253506799	-0.53218186	0.253506799
Diesel Hybrid	-0.227902256	0.163150441	-1.396884094	0.18152339	-0.573765739	0.117961227	-0.573765739	0.117961227
Plug-in Hybrid	-0.170987628	0.150545271	-1.135788769	0.272772381	-0.490129343	0.148154087	-0.490129343	0.148154087
EV	-0.023346888	0.130601287	-0.178764609	0.860366542	-0.300209247	0.253515471	-0.300209247	0.253515471

Source: Created by research paper authors.

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