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Leapfrogging or Stalling Out? Electric Vehicles in China

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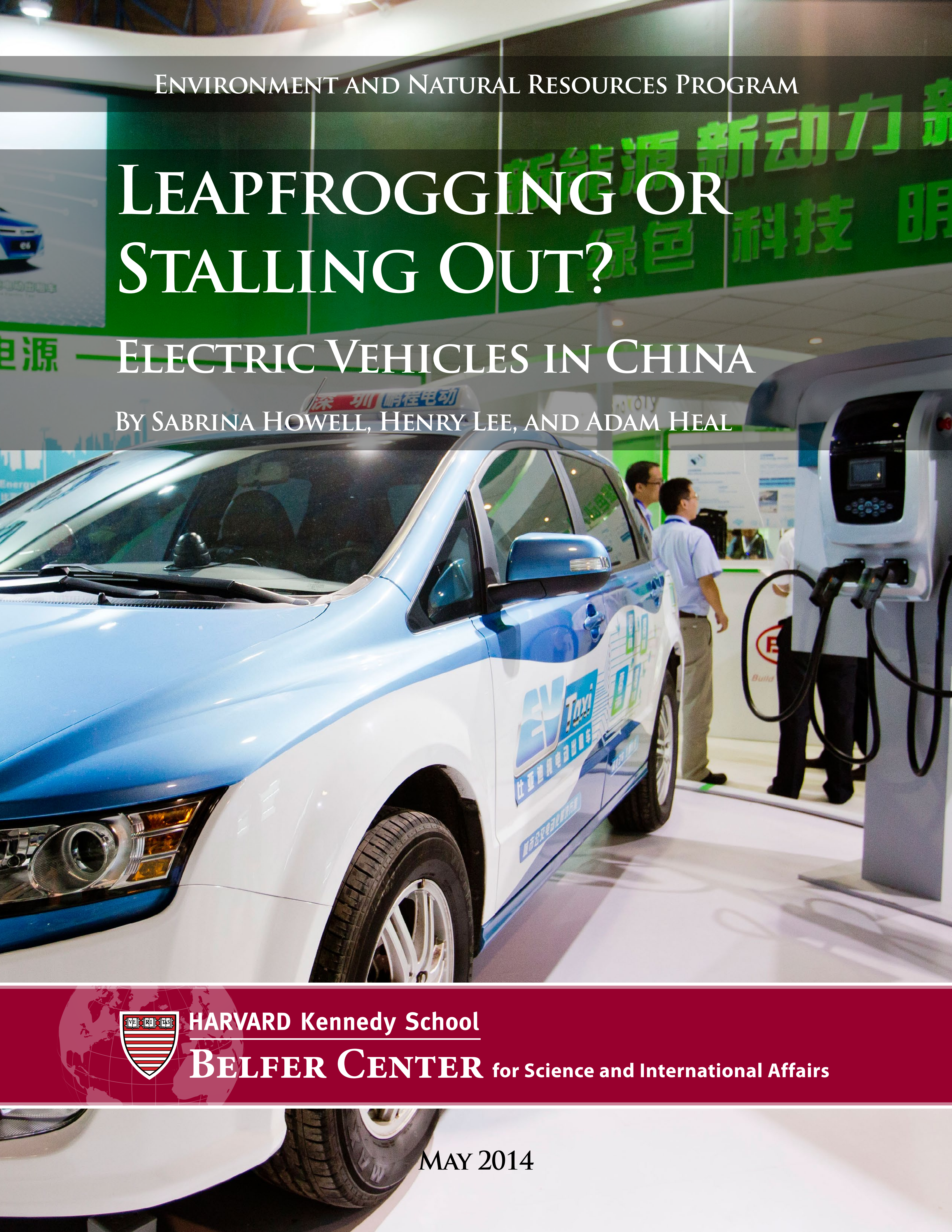

Environment and Natural Resources Program

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By Sabrina Howell, Henry Lee, and Adam Heal

HARVARD Kennedy School
Belfer Center for Science and International Affairs

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Cover photo: A visitor looks at an e6 electric taxi of BYD during the 11th China International Battery, Raw Material, Producing Equipment and Battery Parts Fair, also known as Battery China 2013, in Beijing, China, 17 June 2013.

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Executive Summary

China has ambitious goals for developing and deploying electric vehicles (EV). The stated intention is to "leapfrog" the auto industries of other countries and seize the emerging EV market. Since 2009, policies have included generous subsidies for consumers in certain locations, as well as strong pressure on local governments to purchase EVs. Yet four years into the program, progress has fallen far short of the intended targets. China has only about 40,000 EVs on the road, of which roughly 80% are public fleet vehicles such as buses and sanitation vehicles.

China's EV industry faces the same challenges as companies in the West: a) high battery costs; b) inadequate range between charges; and c) no obvious infrastructure model for vehicle charging.

In addition, China's industry is constrained by four domestic barriers.

1. China's fragmented automobile industry lacks the capacity to acquire or develop world-class EV technologies. To date, attempts to induce foreign companies to transfer technologies via joint ventures have been largely unsuccessful.

2. Trade barriers prevent foreign firms from producing or selling EVs in China. Not only are imported cars ineligible for subsidies, there are also stringent IP transfer requirements for domestic sales of foreign-branded EVs and other "new energy vehicles." Equally important as the international barriers, trade barriers at the city- and province-level prevent an efficient allocation of the EV manufacturing and supply chain within China.

3. The national government's focus on developing high-end EVs that directly substitute for conventional vehicles has distracted Chinese firms from developing a strong domestic market in lower-performing EVs, particularly low-speed EVs. Such an industry, which is currently growing in spite of government policies, builds on China's leadership in electric bicycles.

4. If coal-fired power is used to meet EV electricity demand, the absence of tailpipe emissions will likely be entirely offset by incremental power generation emissions. Without substantial changes in China's power mix, EVs could decrease air quality and worsen health outcomes due to the high toxicity of particulate and sulfur emissions from existing power plants.

Mass EV deployment in China likely requires substantial policy adjustment. In particular, it will be necessary to permit foreign EV technologies relatively free market entry. In turn, this requires greater foreign IP protection. China must also consolidate its domestic industry and place greater emphasis on smaller, cheaper vehicles aimed at domestic, lower-end markets. Finally, if EVs are to contribute to air quality improvement, the government must ensure that the electricity powering EVs is cleaner than the current mix, particularly in Northeast regions of China.

I. Introduction

Three critical and interlinked priorities for China are economic upgrading, environmental sustainability, and energy security. The first priority stems from fear of falling into a "middle income trap," stuck in low value-added manufacturing and dependent on foreign innovation.[1] Second, the health and environmental consequences of energy use have become barriers to further growth. Redirecting the country along a more sustainable development path has become a test of the leadership's ability to meet public expectations. Finally, China's dependence on foreign countries and the open seas for its oil, and, more recently, its coal and natural gas, exacerbates its perception of energy vulnerability.

Electric vehicles exist at the intersection of the three challenges – innovation, the environment, and oil dependency. Examining the Chinese effort to develop an electric vehicle (EV) market offers a window into the country's economics and politics as it confronts these three challenges. China has set ambitious goals for domestic EV development and deployment - 5 million EVs on the road by 2020. The stated goal of the leadership is to "leapfrog" the advanced auto industries of other countries and seize the growing "new energy vehicle" (NEV) market.[2] Initially, China targeted producing 500,000 electric vehicles by 2011, or 5% of total vehicle sales. As China was producing essentially no EVs at the time, these targets were quite ambitious.

Progress has fallen well short of these goals. In mid-2013, China had only about 40,000 EVs on the road, more than 80% of which were public fleet vehicles (e.g. taxis and buses). China EV incentives face the same challenges as the rest of the world: high battery costs, long charging times, and no obvious business model for charging infrastructure.[3] But domestic barriers loom even larger. The country has a weak domestic auto sector, counterproductive trade barriers, a balkanized subsidy and infrastructure program, and uncertainty over standards and technology.

China has just 44 passenger cars per 1,000 people, compared with 423 in the U.S., 517 in Germany, and 453 in Japan.[4] Yet air pollution and traffic congestion plague China. The idea that electric vehicles for private and public use could allow China to leapfrog the internal combustion engine (ICE) and build a clean, high-tech transportation system was a compelling vision. In 2010, New York Times columnist Thomas Friedman wrote: "It will be a moon shot for them, a hobby for us, and you'll import your new electric car from China just like you're now importing your oil from Saudi Arabia."[5] Despite Friedman's forecast, China remains a long way from meeting its ambitious goals.

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1 Interviews with Wang Qing, Division Chief of the Market Economy Division of the State Council Development Research Center and with Fang Jin, Deputy Secretary General of the China Development Research Foundation.

2 State Council (*zhongguo renmin gongheguo guowuyuan* 中华人民共和国国务院). 2012. "Energy Saving and New Energy Auto Industry Development Plan (2012-2020) (*jieneng yu xin nengyuan qiche chanye yu fazhan guihua*节能与新能源汽车产业发展规划（2012—2020年))". June 28. http://www.gov.cn/zwgk/2012-07/09/content_2179032.htm

3 Lee and Lovellette, 2011. Will Electric Cars Transform the U.S. Vehicle Market? An Analysis of the Key Determinates. Belfer Center Discussion Paper. July 2011.

4 World Bank. 2012. World Development Indicators, Passenger cars (per 1,000 people). http://data.worldbank.org/indicator/IS.VEH.PCAR.P3

5 Friedman, Thomas. 2010. "Their moon shot and ours." *New York Times.* September 25.

There are four elements driving China's consistent political support for EVs.

i) Technological upgrading
ii) Energy security
iii) Local pollution reduction
iv) Carbon emissions

Technological upgrading

The Chinese Communist Party (CCP) believes that sustainable economic growth depends on upgrading industry to a higher-value, higher-technology role in the global economic supply chain. The auto industry has been a fundamental factor in China's visions of becoming a global economic power. EV production and sales could play a prominent role in China's strategy to achieve this vision. The party argued that building a large domestic market would offer a launch pad for global expansion, and enable China to forge a commercial lead in a potentially valuable global growth sector.

China's State Council "Energy Saving and New Energy Auto Industry Development Plan 2012-2020" argued that "Sustainable development of the automobile industry, including transformational upgrading, is an urgent task and is important for new economic growth and international competitive advantage. The Plan's intent, based on 'Deng Xiaoping theory,' the 'Three Represents' [of Jiang Zemin], and the scientific development theory [of Hu Jintao], is to use the new energy vehicle industry as a lever to accelerate and transform economic development."[6] In contrast to gas-powered cars, where entrenched foreign competitors would be hard to challenge, authorities argued that battery technologies offered an opportunity to leapfrog foreign competitors.[7]

Energy security: For most of the last three decades, energy security has been a military and economic priority for China. Since 1993, China has been a net importer of oil and will soon pass the U.S. to become the world's largest oil importer.[8] Today over 50% of oil consumed is imported, with transport accounting for around 25% of final consumption.[9] Over 60% of imported oil originates in the Middle East and travels through the Malacca Straits, a potential strategic choke point that could be blocked by powers hostile to China. According to the Ministry of Industry and Information Technology (MIIT), new vehicle sales are responsible for 70% of China's annual growth in gasoline and diesel consumption.[10]

[6] State Council (*zhongguo renmin gongheguo guowuyuan* 中华人民共和国国务院). 2012. "Energy Saving and New Energy Auto Industry Development Plan (2012-2020) (*jieneng yu xin nengyuan qiche chanye yu fazhan guihua*节能与新能源汽车产业发展规划（2012—2020年))". June 28. http://www.gov.cn/zwgk/2012-07/09/content_2179032.htm

[7] "Recharging China's Electric-vehicle Aspirations - McKinsey Quarterly - Automotive - Strategy & Analysis", n.d. https://www.mckinseyquarterly.com/Recharging_Chinas_electric-vehicle_aspirations_2998.

[8] Krauss, Clifford. 2013. "Oil Shocks Ahead? Probably Not." *The New York Times.* October 8.

[9] IEA. "Oil and Gas Security 2012". IEA, 2012.

[10] State Council Development Research Center Information Network (*guowuyuan fazhan yanjiu zhongxin xinxi wang* 国务院发展研究中心信息网). 2013. "China's draft of a new plan to create conditions for new energy vehicle innovation (*zhongguo qicai xinzheng wei xin nengyuan qiche chuangzao tiaojian*中国起草新政 为新能源汽车创造条件.)" August 6.

Concerned about supply disruptions, China has made development of indigenous energy resources, both conventional and renewable, a priority. Thus electrifying the transport sector, which in the near term would rely on electricity generated from domestic coal, could enhance China's energy security, but would simultaneously increase air pollution and reduce public health.

Carbon emissions: Reduced carbon emissions, and greater energy efficiency are important elements in China's 12th Five-Year Plan. Published in March 2011, the Plan includes targets to decrease the energy intensity of the economy 16% by 2015 with a 17% reduction in accompanying carbon emissions (on a 2005 baseline).[11] These are interim targets on the way to a pledged 40-45% reduction in carbon intensity by 2020. Electric vehicles are seen as contributing to this goal, despite the fact that EVs almost certainly cause higher CO_2 emissions in certain regions than conventional cars.

Local pollution reduction: Keenly aware that China houses seven of the world's ten most air-polluted cities, Others within China's government focus on EVs primarily as a means to reduce local urban pollution. Battery Powered EVs (BEVs) have no tailpipe emissions. Power plants tend to have high smokestacks and in some cases are far from the population centers they serve. So EVs can offer urban air pollution reduction without abandoning the personal automobile.

Estimates of automobiles' responsibility for Chinese urban pollution vary widely due to uncertainty about the role of coal combustion. Some members of the foreign press have asserted that internal combustion engines are the dominant source of smog (ozone) and particulate matter, particularly PM2.5.[12] Overall pollution impacts of EVs, however, will depend on the fuel source for electricity, power plant efficiency and pollution abatement investments, and the proximity of those power plants to population-dense areas.

These four drivers have made EVs the object of ambitious and very public government targets. The central government has targeted high-end EVs that can compete with conventional sedans. China has used R&D grants and other incentives to induce automakers to build EVs and generous subsidies to get government provincial governments and consumers to buy them. Central and local governments have initiated a number of pilot subsidy programs, primarily aiming at public fleet deployment. The subsidies are up to ¥60,000 ($9,800) from the central government, and in some cities an additional ¥60,000 from the local government.[13] In six of the pilot cities, private consumers are also eligible for these subsidies. The state-owned electric grid companies have committed to building large numbers of public charging stations.

Though these policies have not yet borne fruit, there is some reason for guarded optimism. Municipalities expected to create the first markets by purchasing electric public fleet vehicles may have missed their targets, but they have deployed significant numbers of public EVs – taxis, police cars, sanitation vehicles and buses. In order to support local automakers and comply with central government directions, a few municipalities seem to have genuinely committed to electrifying a sizable portion of their fleet. In addition to buying vehicles, these aggressive cities – such as Shenzhen and Beijing – have constructed dedicated charging stations to support electric vehicles.

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11 Lewis, Joanna. "Energy and Climate Goals of China's 12th Five-Year Plan". Pew Center, 2011.

12 Larson, Chirstina. 2013. "Chinas autos need to emit less pollution." *Bloomberg BusinessWeek.* February 4; and Watts, Jonathan. 2012. "China quietly shelves new diesel emission standards." *The Guardian.* February 1.

13 Throughout the paper, except where otherwise noted, we use an exchange rate of $1=¥6.12

On the consumer side, the situation is bleaker. The vast majority of Chinese EV models displayed at auto shows have not made it to retail showrooms. Using a new, unique dataset of all domestic Chinese auto sales by model, we find that sales of hybrid (HEV), plug-in hybrid (PHEV), and all-electric vehicles (BEV) combined totaled 3,181 vehicles in 2011, 15,880 in 2012, and 9,720 in the first 8 months of 2013. These numbers include sales to governments for use as taxis and police cars. By comparison, the U.S. in 2012 saw 434,625 HEVs, 14,251 BEVs and 38,584 PHEVs sold.[14] On the infrastructure side, there are still very few usable, public charging stations in China.

The absence of EVs on China's roads is due to a confluence of internal and external factors. First, China faces the same trifecta of critical challenges to EV development as the rest of the world:

- Expensive batteries
- Inadequate driving range (energy density)
- Long charging times for public infrastructure

There is a second trifecta of critical China-specific barriers to EV deployment:

- Deficient automakers
- Trade barriers
- Inadequate Intellectual property protection

China's auto companies have not been up to the task, lacking the design, engineering, assembly and quality controls to produce viable EVs. At the national level, significant trade barriers prevent foreign technology from entering the Chinese market, where it could, in theory, exploit consumer-side subsidies to achieve greater deployment and higher quality products. At the local level, there is a maze of internal trade barriers, including local component requirements for EV production subsidies. These present significant barriers to developing a national EV industry.

Currently, the best EV technologies are owned by firms headquartered in Japan, Germany and the U.S. China's weak intellectual property (IP) regime, as well as extreme technology transfer requirements for NEV market entry, mean that Chinese consumers do not have access to these EV technologies. Thus while Chevrolet and Nissan, for example, sell large numbers of vehicles in China, neither the Volt nor the Leaf is available.

With essentially no government support, China has flourishing low-speed EV and electric bikes (ebikes) industries. Low-speed EVs, essentially upgraded golf carts aimed at consumers who cannot afford a car, are now a common sight in China's rural areas. Looking beyond cars, China is the world leader in ebike production, a sector with strong export potential. Ebikes have been quietly marketed since the mid-2000s and are now ubiquitous on city streets. Technologically simple, ebikes are cheap, quiet, clean, quick-to-charge and have ranges suitable for daily commutes. Ebikes have replaced the bicycle for millions of urban Chinese who cannot afford to buy and park a car. These vehicles are far less glamorous than a potential Chinese Tesla, but they offer a viable market that could be expanded and potentially upgraded to a "real" EV industry.

[14] Data from Electricdrive.org

Section II provides a description of China's EV policy evolution at the national and local levels. Section III examines the state of China's EV industry. Section IV assesses the charging infrastructure needed to support a rapidly developing EV sector. Section V conducts a rough cost comparison between a prototypical Chinese EV and its conventional internal combustion engine substitute. The final section discusses the challenges facing electric vehicle deployment.

II. Policy Evolution

The four drivers of China's consistent political support for EVs since the early 2000s are compelling: technological upgrading, energy security, carbon emissions, and local pollution. The technology upgrading focuses on indigenous innovation and the creation of globally competitive companies that can produce products for the Chinese market which can be sold throughout the world.

The second and third rationales, namely global and local pollution, reflect the fact that the price of gasoline and diesel may not fully incorporate their social costs.[15] The current prices of conventional fuels, combined with the first-mover advantage of incumbents (namely, a well-established liquid fuel distribution system) mean that EVs will need to present a significant cost advantage in order to compete.

China has long been fundamentally decentralized in its operational governance, while focused on unity at the highest, strategic level. With some exceptions, when the central government issues a new policy, the localities (provinces and cities) are responsible for implementation and often financing. From the outside China may appear monolithic, with senior leaders issuing decrees supporting EVs that lower-level officials scurry to implement. In fact, not only are there complex consensus requirements within the central government, ensuring the new policy is in the interest of whichever local officials must carry it out is also critical. After describing central government policy, we will turn to a discussion of how the localities have responded.

A. National Policy Evolution

Two major policy shifts provide the basic backdrop to the EV program. First, in 2000, China began to emphasize reduced energy use and emissions in its auto industrial policy, rather than just expanding production and localizing supply chains. Second, in 2006, "indigenous innovation" (zizhu chuangxin自主创新) became central to the country's economic development plan in its Medium- and Long-Term Plan for the Development of Science and Technology (2006-2020).16 (Note: For a policy timeline documenting more than can be described here, see Appendix A.)

This policy and China's larger effort to support EVs have embraced the notion that technological innovation can come from government and grand planning. The central government defines broad

[15] See Zheng, Siqi and Matthew Kahn. 2013. "Understanding China's Urban Pollution Dynamics." *Journal of Economic Literature,* Vol51; also see Lin, Cynthia and Jieyin Zeng. 2013. "The Elasticity of Demand for Gasoline in China." *Energy Policy.* Vol 59.

[16] State Council (*zhongguo renmin gongheguo guowuyuan* 中华人民共和国国务院). 2006. "National long term science and technology development plan (*guojia zhong changqi kexue he jishu fazhan guihua gangyao* 国家中长期科学和技术发展规划纲要 (2006–2020))." February 9. http://www.gov.cn/jrzg/2006-02/09/content_183787.htm.

priorities and strategic directions, identifying qualitative and quantitative targets for progress (though many interpret these targets as aspirational). Policy tools to achieve innovation goals have generally been supply-side and technology-driven, ignoring the more difficult issues of establishing an institutional environment conducive to innovation and building creative social capital.17

In 2001, China initiated a small-scale research and development (R&D) program to develop new energy vehicle technologies. This program grew rapidly over the course of the decade as the Chinese government became convinced that these technologies could open the door to substantial market opportunities, while mitigating emerging energy and environmental problems. Initially the focus was on the development of fuel-cell vehicles, but soon expanded into Hybrid electric (HEV) and battery electric vehicles (BEV). In addition to differentiated tariffs that protect high-tech sectors, the government appropriated funds to directly support R&D through the National High Tech R&D program (863 Program) administered by the Ministry of Science and Technology (MOST). By the 11th Five Year Plan, China was committing over ¥47 billion to these programs–a six fold increase over 2001 levels. Nearly all the R&D funding, both loans and grants, went to large firms, many state-owned.

The year 2009 marks a turning point for China's EV policy as the government began to focus on rapid deployment.18 In 2009 the central government issued the "Automotive Industry Readjustment and Revitalization Plan" and the ''Notice on New Energy Vehicle Demonstration and Subsidies.''19 These documents called for the production of 500,000 electric vehicles by 2011 (5% of total vehicle sales). To realize these new targets, the government provided a ¥60,000 subsidy for a BEV, ¥50,000 for an advanced hybrid, and larger amounts for electric buses. These subsidies were initially limited to three years from 2010-2012, though they have been extended for PHEVs and BEVs.

China's EV program has primarily relied on government procurement of EVs. It was not until late 2010 that China announced a modest program to provide subsidies to private consumers in five cities - which so happened to be the headquarters of some of the larger Chinese automakers (later expanded to six to include Beijing). It is important to remember that the vast majority of Chinese car buyers were never eligible for these subsidies.

The "Ten Cities Thousand Cars" program (shi cheng qian liang十城千辆) has been China's primary deployment effort. It focuses resources on public sector EVs, such as taxis, buses and sanitation vehicles. The program is the brainchild of Wan Gang, MOST's leader and perhaps China's most aggressive advocate of EVs. Launched in 13 cities in 2009, the program expanded to 25 cities

[17] Serger, Sylvia and Magnus Breidne. 2007. "China's fifteen year plan for science and technology: An assessment." *Asia Policy,* No 4.

[18] China Daily. 2011. "Electric car timeline." *China Daily Europe.* May 13. http://europe.chinadaily.com.cn/epaper/2011-05/13/content_12504537.htm

[19] Finance Ministry (*zhongyang zhengfu caizheng* 中央政府财政). 2009. "Energy saving and new energy vehicle demonstration temporary subsidy extension (*jieneng yu xinnengqiche shifan tuiguang caizheng buzhu zijin guanli zhanxing banfa* 节能与新能源汽车示范推广财政补助资金管理暂行办法)." February 6. http://cn.chinagate.cn/economics/2009-02/06/content_17233183.htm

over the next year.20 The central government provides direct subsidies for vehicle purchase, but local governments administer the program and are responsible for funding charging stations and actually getting the vehicles on the road. Over the course of 2009, the central government was reported to have provided ¥1 billion to local governments, which generated investment of more than ¥8.5 billion in private investment in batteries, motors and other equipment.21

Despite a lack of enthusiasm for EVs from consumers and automakers – the 12th Five Year Plan (2011-2015) designated New Energy Vehicles (NEVs) as one of China's seven "Strategic and Emerging Industries." MOST's "12th Five-Year Plan for Electric Vehicles," released in 2011, pushed back the target of deploying 500,000 BEVs and PHEVs to 2015 (it was originally 2011). The plan also called for 2,000 charging or swapping stations, containing 400,000 individual charging poles to be erected over the five-year period.

In 2012, the more high-level "State Council's Energy-saving and New Energy Automotive Industry Development Plan" was issued, supporting MOST's targets. The State Council argued that China must:

"Speed up the development of energy efficient cars and new energy vehicles, both to alleviate the pressure on energy and the environment and to address the pressing need for sustainable development of the automobile industry. Promoting EVs can accelerate the transformation and upgrading of the automobile industry, foster economic growth, and provide an opportunity to achieve international competitiveness in a strategic sector." 22

The statement suggests that stimulating technology innovation for global economic advantage motivates China's commitment to EVs as much as energy security or pollution mitigation. Throughout the document, technology upgrading seems to take precedence over other rationales. If China's EV policies were driven exclusively by energy or environmental factors, the design and implementation of those policies would be different. In its emphasis on homegrown technology, China inadvertently limits its ability to realize greater energy and environmental benefits that might ensue from a different NEV policy.

First, China's EV policies rest on two policy instruments – targeted subsidies and government procurement – both of which are limited to particular regions. Subsidies are very expensive and not always effective, in part because market players are uncertain about their political and fiscal sustainability. These instruments have also shown limited ability to stimulate innovation at either the point of production or the market place. There has been very little discussion of a wider portfolio of demand pull options, which might include broader subsidies available to all EVs and all

[20] The original 10 cities were Beijing, Shanghai, Chongqing, Changchun, Dalian , Hangzhou, Jinan , Wuhan, Shenzhen and Changsha. The three added before launch were Kunming , Nanchang, and Hefei. In early 2010, Guangzhou, Haikou , Suzhou, Tangshan , Tianjin , Xiamen and Zhengzhou were added to the list, and finally at the end of 2010 Chengdu, Hohhot, Nantong , Shenyang and Xiangfan were added.

[21] Du Jidong (杜纪栋). 2010. "Ten Cities Thousand Vehicles: Accelerating China's Battery Electric Vehicle Market Development (*shi cheng qian liang: jiasu zhongguo chun diandong qiche chanye hua* 十城千辆：加速中国纯电动汽车产业化).". October 14, 2010. http://www.evtimes.cn/html/201105/26062.html

[22] State Council (*zhongguo renmin gongheguo guowuyuan* 中华人民共和国国务院). 2012. "Energy Saving and New Energy Auto Industry Development Plan (2012-2020) (*jieneng yu xin nengyuan qiche chanye yu fazhan guihua*节能与新能源汽车产业发展规划（2012—2020年))". June 28. http://www.gov.cn/zwgk/2012-07/09/content_2179032.htm

consumers, higher conventional fuel taxes, feebates taxing buyers of fuel inefficient vehicles, or even discriminatory road tolls. HEVs and natural gas vehicles, which are more cost competitive in China than pure EVs, are not eligible for subsidies. China has also essentially barred foreign EV imports, which might have hastened consumer acceptance.

Second, instead of allowing market competition to drive improvements, China has focused on producing high-end EVs that can compete with conventional sedans. This undermines China's strength in the much less technically demanding sectors of low-speed EVs and ebikes. By 2020, the State Council Plan targets maximum speeds of no less than 150 KM/hr, ranges for BEVs of 150 kilometers and battery prices of $245 per Kwh by 2020.23 If the goal is to leapfrog existing technologies and develop technological options that will revolutionize the global marketplace, wide-scale private deployment in local markets becomes less urgent. An alternative would be to set safety standards to protect consumers and efficiency standards to meet energy and environmental goals, but allow the competition to determine the rate at which improved technologies are deployed.

Third, China's subsidies, designed to accelerate the technological innovation process, change every 3-4 years. This uncertainty is equally problematic in the U.S., where tax credits for deploying energy technologies have even shorter life times. The result in both countries is underinvestment in new energy technologies. When the private subsidy program in China ran out at the end of 2012, it took the government six months to renew it. Manufacturers discount the subsidies, since they are not certain that they will be sustainable. In addition, if the government suggests that new subsidies for a different portfolio of technologies are likely to be promulgated in the near term, manufacturers have an incentive to delay spending until the subsidy is available. Often these new subsidies never materialize. For example, hybrid vehicles were not included in the renewed subsidies.

Fourth, Chinese cities often erect internal trade barriers forcing buyers of both final and intermediate goods to only purchase locally produced goods. For example, governments in Guangzhou will only buy vehicles from BYD—the large auto company in that province, while the only taxis that you will find in Beijing are from the Beijing-Hyundai joint venture and Shanghai only buys from SAIC-VW. In a country in which the auto manufacturers are major economic engines in a single province, local efforts to discriminate in favor of their local producers are understandable. However these internal barriers are not conducive to building an industry to leapfrog technological barriers.

[23] Specifically, by 2015 Chinese BEVs and PHEVs should have maximum speeds no less than 100 km/hr, with pure electric driving ranges of no less than 150 and 50 km, respectively. The battery should have 150 Wh/kg of specific energy (power), and the cost should drop to ¥2 /Wh ($327/kWh) or less, with a 2000 cycle life or more than 10 years. By 2020, they seek a battery with 300 Wh/kg and a cost of ¥1.5/Wh ($245/kWh). Source: State Council (*zhongguo renmin gongheguo guowuyuan* 中华人民共和国国务院). 2012. "Energy Saving and New Energy Auto Industry Development Plan (2012-2020) (*jieneng yu xin nengyuan qiche chanye yu fazhan guihua*节能与新能源汽车产业发展规划（2012—2020年))". June 28. http://www.gov.cn/zwgk/2012-07/09/content_2179032.htm

The central government is working to change these intra-national trade barriers stating that:

> "Non-local brands must make up no less than 30% of the vehicles deployed in the participating cities (those participating in the pilot subsidy program). Cities may not establish or covertly establish barriers or restrictions to the purchase of outside brands of vehicles." [24]

Whether these directions result in changing the practices of provincial governments remains to be seen.

China recently expanded the Ten Cities Thousand Vehicles program in a few focus cities to create "pilot regions." Specifically, the central government specified Beijing, Tianjin, the Yangtze River Delta (surrounding Shanghai), and the Pearl River Delta (surrounding Guangzhou) as priority areas. In these megacities, consumers will be eligible for both the central government and local government subsidies. These subsidies will decline 10% each year through 2015, and are targeted towards BEVs, PHEVs and fuel cell vehicles. However, the central government is demanding more from these pilot regions: the targets are more aggressive, and the pilots will have to pass annual evaluations in order to remain eligible for subsidies. The central government will conduct annual performance evaluations of each pilot. In summary, in 2013, China is focusing more intensively on a few regions, and demanding improved performance by the local governments.

B. Local Government Support

Certain provincial governments, like those in Shenzhen and Chongqing, have become important advocates and stakeholders in EV innovation, supporting the auto industry's development.[25] The initiative of these local governments has determined the success of the larger program. The State Council Development Research Center White Paper presents three existing regimes and discusses them as models for broad deployment: [26]

1. Shenzhen Putian Leasing Model: In this model pursued by the Shenzhen government, the state-owned company, Putian (also called Potevio), builds the charging stations, and the Shenzhen government at great expense buys electric buses, mostly from BYD. Then the government sells the buses without their batteries to local bus companies, making them quite cheap, and leases the batteries over 8-year terms. Government ownership of the batteries allows Putian to monitor battery conditions, charging state, and driving conditions in real time, alerting bus operators when something might be wrong.

2. Hefei Jianghuai Direct Sales Model: This is the most straightforward model and involves selling highly subsidized vehicles directly to private buyers. The auto company

[24] Finance Ministry (*zhongyang zhengfu caizheng* 中央政府财政). 2013. "Notice on continuing to promote new energy vehicles (*guanyu jixu kaizhan xin nengyuan qiche tuiguang yingyong gongquo de tongzhi*关于继续开展新能源汽车推广应用工作的通知)." September 17. http://www.gov.cn/zwgk/2013-09/17/content_2490108.htm

[25] Liu, Yingqi and Ari Kokko. 2013. "Who does what in China's new energy vehicle industry?" *Energy Policy* 57.

[26] State Council Development Research Center Enterprise Research Center (*guowuyuan fazhan yanjiu zhognxin qiye yanjiu suo* 国务院发展研究中心企业研究所). 2012. "National policies to promote an innovative business model for electric vehicles (*woguo dui diandong qiche shangye moshi chuangxin de tansuo ji ying caiqu de zhengce* 我国对电动汽车商业模式创新的探索及应采取的政策)."

Jianghuai (JAC), which is majority owned by the Anhui provincial government, sold 585 EVs to individuals by the end of 2012, taking advantage of the central and city subsidies and then adding a further “company” subsidy of ¥30,000. Together, these subsidies reduced the price to ¥65,000, which is on par with comparable conventional cars. This program demonstrates that if the subsidies are large enough, it is possible to sell EVs to private consumers through the market.

3. Hangzhou Model: This is a battery-swapping model, which the city of Hanghzou is focusing on for taxis and rental cars. Hangzhou has 200 BEV taxis that recharge by swapping batteries at a few stations. The advantages are that less land is required for charging stations and drivers do not need to bother with the long charging time.

However, many of the local programs which receive attention in the press are less than they seem. For example, Shanghai has been the most active EV deployment center. The local champion is the Shanghai Automotive Industrial Company (SAIC), which produces the Roewe E50 pure EV. Based on the Range Rover name, whose technology SAIC had previously licensed, the Roewe marque is supposed to be SAIC’s upscale brand. Most Shanghai EV purchases can be expected to be E50s. For example, local rental car company eHi Car Service Co announced in May, 2013, that it will add 500 E50s to its 10,000 vehicle fleet. [27]

Shanghai’s auto manufacturing-intensive Jiading district, in the northeastern suburbs, positioned itself as China’s “international EV pilot zone” in early 2011. The district government offers a further ¥15,000 cash rebate to EV consumers. Additionally, Shanghai offers ¥30,000 subsidy for PHEV purchases and ¥40,000 for BEVs.[28]

Today there appear to be only three pieces of EV-related infrastructure in Jiading: the EV testing center, the SAIC Motors EV showroom, and a single set of State Grid charging stations. SAIC’s single location for purchasing its Roewe E50s is this showroom, the outside of which is depicted in Figure 1 below. A small facility with a rather bedraggled exterior, the outdoor parking spots have exposed wiring where EV charging stations appear to have been removed. A handful of EVs were attractively displayed inside, but in strong contrast to the next-door Audi dealership there were none parked outside, suggesting less than robust sales.

27 He Wei. 2013. “R&D Support needed for EV industry.” *China Daily Asia.* May 31. http://www.chinadailyasia.com/business/2013-05/31/content_15075198.html

28 He Wei. 2013. “R&D Support needed for EV industry.” *China Daily Asia.* May 31. http://www.chinadailyasia.com/business/2013-05/31/content_15075198.html

Figure 1: SAIC New Energy Vehicle Showroom, Jiading District, Shanghai[29]

III. Innovation and China's Auto Industry

Local government support for EV policy is closely tied to the political economy of the auto sector and in particular the push for greater concentration. The 1994 Automotive Industry Policy required the top auto SOEs to merge with or acquire other companies. Yet this was an unequivocal failure – today, there remain over 90 domestic automakers in China. The local governments own and depend for revenue on local auto firms and their suppliers, and are unwilling to see them close or move. The high concentration and economies of scale in the global auto industry suggest that many Chinese auto firms would exit if local support were removed.

In 2009 Beijing called for the industry consolidate to around 10 firms, about half of which would be large, centrally owned SOEs with annual production of more than 2 million vehicles (e.g. FAW, Chang'an, Dongfeng), and half would be provincially owned with production of at least 1 million vehicles (e.g. SAIC, Chery, Guangzhou). At the same time, automakers producing EVs are more likely to be favored and thus exempt from consolidation pushes. Therefore, the renewed stress on concentration has been one rationale for aggressive local government support for EVs. . Local officials want "their" companies to survive consolidation, and have thus provided local subsidies for purchases of HEVs and BEVs that add to the central subsidies.[30]

The auto industry has consistently been a pillar industry from the Chinese government's perspective, as well as an aspirational one; building strong, world-class auto companies is perceived as essential if China is to join the ranks of the global economies. The U.S., Japan, Germany, and South Korea all have automakers whose products are sold throughout the world, so why shouldn't China strive for similar success in this sector?

It is worth noting that becoming a world-class automobile original equipment manufacturer (OEM) is a very tall order. Automobiles are very difficult to make well and at scale. Each vehicle includes

[29] Photo by Sabrina Howell, June 2013

[30] Zhang, X., Yang, J., Sun, B., and Wang, J., 2009, Study on the Policy of New Energy Vehicles in China, Paper Presented at Vehicle Power and Propulsion Conference, 7–10 September, Dearborn, MI.

at least 15,000 parts, ranging from tiny motors and sensors to doors and the engine. Each part must fit together perfectly in order to generate the product that consumers expect when they buy even the most down-market vehicle.

Starting in 1982, the government's goal in what we term the "JV Policy" was to access foreign technology in exchange for market access. Top multinational automakers were invited by the government to form joint ventures (JVs) with a specific Chinese domestic firm. The foreign firm could own no more than 50% of the joint enterprise. The idea was that through JV manufacturing, foreign firms would transfer technology to their Chinese partner.

This notion of technology transfer was quite vague; it was hoped that simply being in the presence of the foreign automakers would cause technology transfer to Chinese firms as though by osmosis. In later years, explicit IP transfer would be required. Yet technology transfer is not easy to force. In the automotive industry, much of the research and design capability is highly tacit. Foreign firms kept their design centers in their home countries, and have rarely manufactured their latest technologies in China.

The first JV was signed in 1984 between Volkswagen (VW) and Shanghai Automotive Industrial Company (SAIC). The Chinese negotiating with VW did not know what to ask for; they did not know what technology should be transferred or the ideal contractual arrangement. By the mid-1990s it was clear that very little, if any technology had been transferred. The 1994 Automobile Policy contained specific technology transfer requirements, in particular that the joint enterprise must have "the capacity for manufacturing products which attain the international technological levels of the 1990s."[31] The government sought (and still seeks) to create large China-based multinationals – *jituan* – out of the domestic JV partners. These Chinese auto firms would ultimately compete with the foreign firms both on Chinese soil and abroad.

To try its hand with a bit more bargaining power – and to put pressure on VW – SAIC signed a second JV agreement with GM in 1997. GM aggressively marketed itself as the purveyor of useful technology, and established a joint research center with SAIC called the Pan Asia Technical Automotive Center (PATAC). However, the center was and is used to tweak existing Buicks, Chevrolets and Cadillacs for the Chinese market, rather than design new vehicles from the ground up.[32] Today, nearly every major automaker has at least one JV in China, but there is essentially no high-level design work done within the country.

The State Council in 2006 issued "The National Medium- and Long-Term Program for Science and Technology Development (2006–2020)," calling for *zizhu chuangxin (*自主创新*); zizhu* means "indigenous" or "self-owned," and *chuangxin* means "innovation." A primary conduit for indigenous innovation was to be EV development. To meet this goal, the Chinese government restricted EV imports and demanded more stringent technology transfer from foreign firms. In practice, these amount to trade barriers preventing foreign technology from entering China. In 2009, the MIIT required that in order for an EV to be sold, whether imported or not, a domestic Chinese firm must

31 Walsh, Kathleen A., 1999, "U.S. Commercial Technology Transfers to the People's Republic of China," A Report to the Office of Strategic Industries and Economic Security, Bureau of Export Administration, www.bis.doc.gov.

32 Tang, Rachel. 2012. "China's Auto Sector Development and Policies: Issues and Implications." Congressional Research Service Report for Congress.

be capable of "displaying mastery" over key EV components: the motor, inverter, and battery.[33]

This requirement is the reason that there are no Nissan Leafs or Chevy Volts in China, along with the fact that imported vehicles are not eligible for subsidies. The technology transfer requirements do not apply to HEVs, which are primarily gasoline-powered.[34] Toyota began producing its first generation Prius in 2005 at the FAW-Toyota plant in Changchun, the first time a Prius was built outside of Japan. The vehicles were built from kits imported from Japan, including all the key powertrain components.[35] Production halted in in 2009, but resumed in 2011 with the 3rd generation Prius. However, Toyota has struggled to achieve high sales volumes, primarily because the Prius is not eligible for any government subsidies.

Despite increasing bargaining sophistication on the Chinese side of the table, the reality after several decades of JV experience is that little technological capacity, particularly for new design, has been transferred. In a 2009 article, auto analyst Yang Jian concludes:

> "Two-and-a-half decades have passed and dozens of such joint ventures have been built in China. But no domestic automaker has achieved what the government wanted. While some own-brand cars are built on platforms transferred from global automakers, almost all of the rest are products of the reverse engineering of international models. Some domestic firms continue to resort to outright copying."[36]

In other sectors, such as shipbuilding and oil production, large state-owned firms have competed successfully on quality and cost in the global marketplace. Yet in autos, the joint venture industry structure effectively eliminated incentives to learn for the incumbent domestic firms. Eventually, Chinese entrepreneurs established more productive independent automakers, and these firms have been the most successful EV builders, but high import tariffs and weak export incentives reduced their incentives to reach the global technological frontier as well.

33 Interview with Wang Xiaojian, head of NEV program at SAIC, and US Trade Representative. 2011. "National Trade Estimate (NTE): China." Available at http://www.ustr.gov/webfm_send/2694

34 Keith Bradsher, "Hybrid in a Trade Squeeze," New York Times, September 5, 2011.

35 Greimel, Hans. 2011. "Toyota will make hybrid parts in US within 4 years." *Automotive News.* September 17. http://www.autonews.com/article/20110917/OEM01/110919860/1329#

36 Yang Jian, 2009. "Chinese Car Companies Resort to Buying Brands Rather Than Creating Them." *Automotive News China*, July 15.

IV. State of the Chinese Electric Vehicle Industry

The perceived Chinese determination to dominate the future EV industry has at times sent shockwaves through the West. A 2010 article in *Foreign Policy* on the coming global battery race concluded that "while U.S. officials have been sweeping in their rhetoric, China has been breathtaking in the scale and specificity with which it is ordering up an electric-car industry."[37]

Unfortunately, China's automakers were ill equipped to develop EVs. As described in the previous section, three decades of policy aiming at technology transfer from foreign firms resulted in very little actual technology transfer. China is lagging behind its own targets and also its competitors. A McKinsey study constructed an index to gauge a nation's EV readiness in terms of both supply and demand. It concluded that in terms of overall readiness China fell from 3rd place in June 2010 to 5th in January 2012, behind Japan, the US, France and Germany.[38]

Electric Vehicle Production and Sales in China

Worldwide, about 186,600 passenger car EVs (PHEVs, BEVs and FCEVs) had been sold as of the end of 2012, of which China is responsible for only 11,573, or 6.2%.[39] Table 1 below shows deployment by country. China has focused a larger share of its EV resources than other countries on buses and sanitation vehicles instead of passenger cars.

Table 1: National stock of EVs (passenger car PHEVs, BEVs and FCEVs) at end 2012[40]

Country	Total # EVs on the Road	Percent of world total
U.S.	71,174	38%
Japan	44,727	24%
France	20,000	11%
China	11,573	6.2%
UK	8,183	4.4%
Netherlands	6,750	3.6%
Germany	5,555	3%

About 70% of the EVs actually in use in China are through the 10 Cities 1000 Vehicles program. As of April 2013, a Tsinghua-MIT-Cambridge study reported to MOST that all the cities in the program had only deployed 27,400 NEVs (of which 10,495 were hybrid buses) and installed 8,107 charging poles, at a total cost of ¥8.8 billion.[41] All but 4,400 of the 27,400 were public

37 Levine, Steve. 2010. "The Great Battery Race." *Foreign Policy.* November.

38 "Recharging China's Electric-vehicle Aspirations - McKinsey Quarterly - Automotive - Strategy & Analysis", n.d. https://www.mckinseyquarterly.com/Recharging_Chinas_electric-vehicle_aspirations_2998.

39 International Energy Agency. 2013. "Global EV Outlook." April. Clean Energy Ministerial and IEA Report.

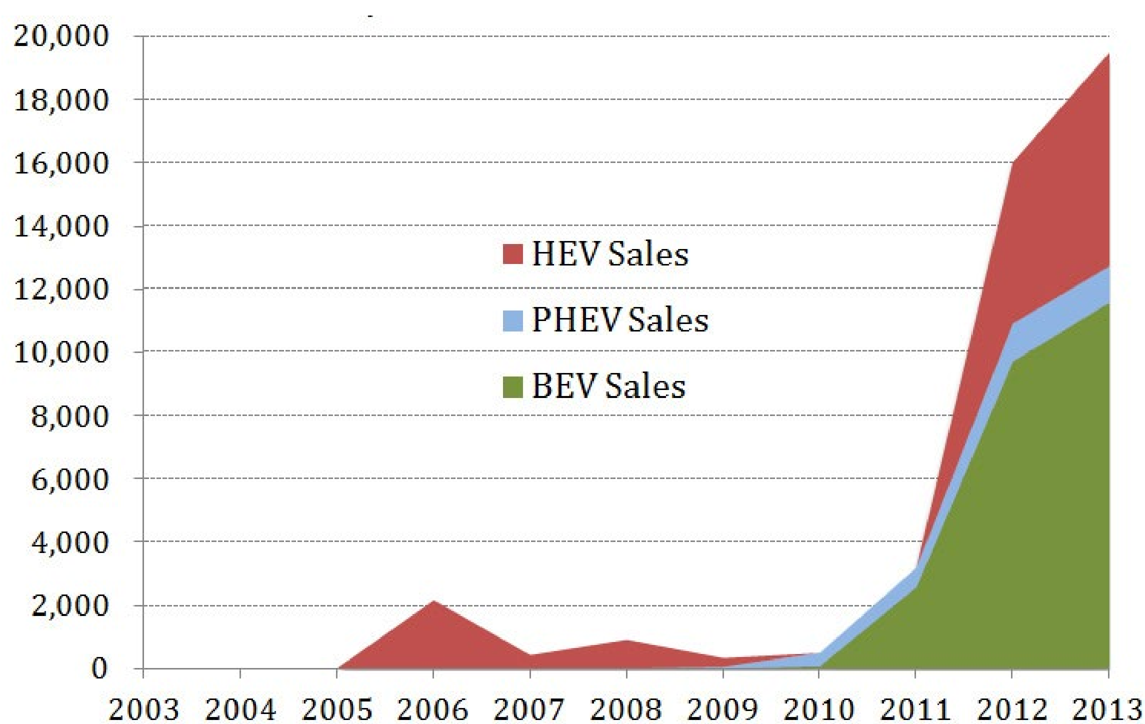
40 International Energy Agency. 2013. "Global EV Outlook." April. Clean Energy Ministerial and IEA Report.

41 Wu, Jianping. 2013. "The development strategy of clean-energy vehicles in China." Tsinghua University-University of Cambridge-MIT Low Carbon Alliance Future Transport Research Center, Presentation for MOST. http://www.iea.org/media/workshops/2013/egrdmobility/Wu_clean_energy_vehiclesinchina.pdf

vehicles such as buses, taxis and sanitation vehicles.[42] Many cities were encouraged to set far more ambitious targets than MOST's 1,000 vehicles. But by July 2012, only 4 of the cities (Hangzhou, Zhengzhou, Suzhou, and Beijing) had achieved more than 30 percent of their targets for the end of 2012 deadline of the first phase of the program.[43]

In line with the overall dominance of foreign brands in China's auto market, the first EV – indeed, in Chinese terminology, the first "new energy vehicle (NEV)" – sold in China was the Toyota Prius, manufactured at the FAW-Toyota joint venture plant in Sichuan from 2005. By 2010, there were 10 NEVs available for sale, half of which were foreign branded (and all of those were hybrids). Most of the auto companies that have tried to produce EVs over the past decade received 863 R&D Program support. Yet the dozens of Chinese-branded EVs routinely displayed at Chinese auto shows rarely make it to auto showrooms for private consumption. Appendix C contains a list, compiled by the authors, of all the light duty EVs approved for sale by the MIIT. The column indicating whether the model is actually available for sale shows how many of these are simply "prototypes" or "concept vehicles."

Figure 2: Electric Light Duty Vehicle Sales in China, 2003-2013[44]



42 Wang Qiuman (王秋鳗), Fu Xiaokang (傅小康). 2013. "Charging is hard: After two years of promotion only 20,000 vehicles have been sold (*chongdian nan: tuolei xin nengyuan qiche 2 nian jin maichu 2 wan liang* 充电难：拖累新能源汽车 2年仅卖出2万辆)". China Economic Weekly (*zhongguo jingji zhoukan*中国经济周刊). April 2. http://auto.people.com.cn/n/2013/0402/c1005-20993730.html

43 Tang Liuyang (唐柳杨) , Li Shaoyi (李绍仪). 2012. "The market is not interested in fulfilling the goals of the Ten Cities Thousand Vehicles new energy vehicle program (*shichang dui xin nengyuan che bugan xingqu shi cheng qian liang mubiao luokong* 市场对新能源车不感兴趣 十城千辆目标落空.)" December 3. First Financial Daily (*di yi caijing ribao* 第一财经日报). http://news.hexun.com/2012-12-03/148608685.html

44 State Council Development Research Center Intranet Database of Auto Model-level production and sales

Responding to intense government pressure, a number of Chinese automakers did actually try to sell EVs in 2012. Figure 2 shows sales between 2003 and 2013. It is constructed using model-level national sales data for light duty vehicles at the brand-model level. The data comes from two sources: the State Council's Development Research Center intranet and the China Automotive Technology and Research Center (CATARC). In some instances, automakers have given EVs for free to local governments for use in public fleets. This helps explain why numbers of deployed and sold vehicles do not always align.

Table 2 shows sales by model in 2011, 2012 and 2013, as well as model characteristics like range and battery type. Clearly, automakers that are *not* central state-owned and *not* in joint ventures with foreign automakers have led the way, particularly on all-electric vehicles. In particular, both BYD and Chery were the only companies to actually sell EVs in 2011. Many new models became available in 2012 and 2013, bringing the total number of models with positive sales to 20. But by comparison, in the US in 2013 automakers offered 12 models of plug-in vehicles and 40 hybrid electric models.

The puzzle of reasonably high quality EVs simply not being in showrooms is explained in part by the gap between automakers' innovative capacity and government expectations. Much about developing and applying new technology is tacit, and hard to transfer, whether by legal or illegal means.

Table 2: China's EV Sales by Brand, 2011-2013

Parent	OEM	Brand	Model	车型	Class	Drivetrain	Battery	Range (km)	Sales 2011	Sales 2012	Sales 2013	Price (yuan)
Beijing Auto (BAIC)	BAIC	Beiqi	E150 EV	E150电动车	Sedan	BEV	Li-ion	140	-	644	1466	249,800
Beijing Auto (BAIC)	BAIC	Beiqi	Senova EV (Shenbao/C70)	绅宝EV	Sedan	BEV	Li-ion	150	-	-	52	300,000
BYD	BYD	BYD	E6	E6	Compact Sedan	BEV	LiFePO4	330	401	1690	1544	300,000
Chang'an	Chang'an	Chang'an	CX30 EV	CX30电动车	Sedan	BEV	LiFePO4	160	-	100	117	160,000
Chang'an	Harbin HF Automobile Industry Group (Hafei)	Hafei	Saibao EV	赛豹电动车	Sedan	BEV	Li-ion	180-210	-	281	1	180,000
Zotye Group	Hunan Jiangnan Auto	Zotye	M300 EV	M300	Sedan Hatchback	BEV	LiFePO4	180	-	134	220	250,000
Zotye Group	Hunan Jiangnan Auto	Zotye	TD100 EV (5008 EV)	众泰TD100	SUV	BEV	LiFePO4	200	-	845	236	210,000
Jianghuai	Jianghuai Automobile Co	JAC Motors	J3 (Tongyue, iEV)	同悦电动车	Sedan	BEV		150	-	2485	1309	65,000
Dongfeng	Dongfeng Nissan	Venucia	E30	启辰 E30	Compact Sedan	BEV	Li-ion	160	-	-	216	
Chery	Chery Automobile Co	Chery	QQ3 EV	QQ3 电动车	Compact Sedan	BEV	Lead-acid	100	2167	3129	5727	49,800
Chery	Chery Automobile Co	Riich	M1 EV	瑞麒M1电动车	Compact Sedan	BEV	LiFePO4	120	-	152	216	149,800
Shanghai Auto (SAIC)	SAIC Motor Corporation	Roewe	E50	荣威E50	Compact Sedan	BEV	LiFePO4	180	-	238	409	234,900
Shanghai Auto (SAIC)	Shanghai GM	Sail	Sail Springo EV	赛欧电动车	Compact Sedan	BEV	LiFePO4	130-200	-	14	69	258,000
BYD	BYD	BYD	F3DM	F3DM	Sedan	PHEV	LiFePO4	100 electric	613	1201	1005	169,800
BYD	BYD	BYD	Qin	秦	Sedan	PHEV	LiFePO4	70 electric	-	-	142	189,800
Chang'an	Chang'an	Chang'an	CX30 Hybrid	CX30混合动力	Sedan Hatchback	HEV	NiMH		-	76	0	100,000
Guangzhou Auto (GAC)	GAC Toyota	Toyota	Hybrid Camry	凯美瑞2.4L混合动力	Sedan	HEV	NiMH		-	119	0	319,800
Guangzhou Auto (GAC)	GAC Toyota	Toyota	New Hybrid Camry	新凯美瑞2.5混合动力	Sedan	HEV	NiMH		-	2164	5547	300,000
Shanghai Auto (SAIC)	Nanjing Auto	Roewe	R750 Hybrid	R750 1.8L混和动力	Sedan	HEV	NiMH		-	-	387	236,800
Shanghai Auto (SAIC)	Shanghai GM	Buick	New Lacrosse Hybrid	新君越2.4混合动力	Sedan	HEV	Li-ion		-	308	350	249,900
FAW	FAW Toyota	Toyota	Prius	普锐斯	Sedan Hatchback	HEV	NiMH		-	2434	513	259,800
								TOTAL:	3181	16014	19526	

Among the vehicles that are actually for sale, high prices have been a deterrent. For example, in 2010, BYD's plug-in hybrid F3DM sedan, the only PHEV in China, sold for ¥149,800, compared with ¥59,800 for the equivalent F3 conventionally-powered model. There have also been serious quality issues with Chinese EVs, leading consumers to believe they are unsafe. Safety is a major concern among Chinese car buyers. The low quality of domestic-branded EVs has resulted in a handful of well-publicized accidents, including fires in Zotye and BYD electric taxis (both privately owned companies without JVs). The latter fire killed the three passengers. Both companies, were silent about the accidents.[45]

45 Yang Jian. 2013. "What China's auto execs can learn from Elon Musk." *Automotive News China.* November 11.

Foreign Automakers

Many of the foreign companies with joint ventures in China have EV technology and expertise. However, they have not deployed these technologies in China due to what they believe are restrictive technology transfer and import tariff requirements. The first foreign-branded plug-in EVs to be sold in China were Tesla Model S BEVs delivered to their buyers personally by Tesla CEO Elon Musk in late April 2014. The Model S is prices at $121,000 in China, compared to $81,000 in the U.S. is available for sale in China. For the foreseeable future, Tesla is unlikely to command more than a small niche in China's luxury market.[46]

The experience of GM's Chevy Volt is illustrative of the problem. Around the 2010 Clean Energy Ministerial, GM announced plans to export Volts to China by the end of 2011. As an initial step, two Volts were shipped for the 2010 Shanghai World Expo.[47] China, however, denied the Volt any subsidies since GM refused to transfer the Volt's technology to a local firm. With tariffs and no subsidies, the Volt costs about $79,000 in China.

In recent years, the Chinese government has encouraged the JVs between foreign and Chinese auto companies to establish joint brands. Rather than making Toyotas in one plant and Guangqi GAC vehicles in another, the goal was for JVs like GAC-Toyota build a new brand aimed at the Chinese market together, through which process greater technology transfer might occur. Further, the government urged all automakers to build an EV, but required onerous IP transfer for foreign firms bringing outside EV technology to China. The automakers' solution has been a number of new domestic brands with EV options. These generally employ outdated EV technology and an existing foreign platform. An example is the new Shi Lang (Ranz) brand from FAW-Toyota, which produces the Shilang EV (currently only deployed in Tianjin for the city's taxis). The Shilang EV is based on the Toyota Corolla frame. Similarly, BMW-Brilliance has the Zinoro brand with the Zinoro 1E, which is an electric version of the BMW X1. And Dongfeng-Nissan has the Kai Chen brand with the E30 EV. The list goes on. These new brands do not carry the cachet of the foreign brand, and their expensive EVs seem unlikely to be popular.

Low Speed EVs and Ebikes

Some prominent voices in China's EV sector are starting to advocate for low-speed EVs. These EVs are small and very light weight, allowing them to use a much smaller and simpler battery than full-size cars. They are perhaps more appropriate for the Chinese market from both supply and demand perspectives.

Chinese policymakers have focused their EV strategy on the major automakers, calling on them to make EVs like the Leaf or Volt that are substitutes for relatively high-end sedans. However, given the relative strengths of Chinese manufacturers, and the needs of the Chinese middle class, this may be precisely the wrong place to start. With low-speed EVs, entry by entrepreneurs is easier as the technology is simpler and competition not as fierce. This plays to China's advantage since the large state-owned incumbent auto firms are not particularly innovative.

The hundreds of millions of Chinese who cannot afford conventional cars may present a powerful

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46 Trefis. 2014. "Tesla expands into China but should only be a small player in the luxury market." May 1.

47 GM. 2010. "Chevy Volt Arrives in China, Goes on Sale There in 2011." September 3. http://gm-volt.com/2010/09/03/chevy-volt-arrives-in-china-goes-on-sale-there-in-2011/

market for cheap, low-speed EVs. Some small start-ups, like Shifeng, are developing low-cost mini e-cars targeted at price conscious rural consumers. These have limited range (100-120 km) and speed (50-60 km/h) but cost a fraction of the typical hybrid or battery sedans. For instance the Shifeng brand car sells for ¥31,500 compared with ¥300,000 for the BYD e6. While promising, many of these small firms are unlicensed and vulnerable to regulation. They also use cheap lead-acid batteries that are known to be polluting.[48]

Figure 3: Kandi EVs Roll off the Assembly Line, 2012[49]

In 2011, Ouyang Ming Gao, director of the State Key Laboratory of Automotive Safety and Energy, astutely pointed out that "the battery range in the U.S. is required to be above 60 km a day, but in China, the range can be lower, given the fact that China has a denser population and people live closer to working places." He also noted that "In China, slow and small-power recharge should be suitable for the majority of drivers."[50]

Privately owned Geely, one of China's most successful automakers, announced in April, 2013 a joint venture with Detroit Electric to develop EV components, particularly motors and drive trains, for the Chinese market, as well as to assemble final vehicles. The company aims to release a BEV version of Geely's Emgrand EC7, a Honda Civic-like sedan, by 2014. Yet Geely's famous founder and chairman, Li Shufu, told a press conference in March, 2013, that low-speed EVs should be prioritized. "Low-speed electric vehicles have many advantages. They are suitable for short driving ranges."[51]

In 2009, Geely formed a ¥1 billion JV with Kandi Technologies to build BEV minicars for urban commuters. Kandi Technologies is a major new player in China's EV market, but it does not show up in Table 2 as Beijing has not thus far deemed it a "real" EV producer. Privately-owned Kandi produces ATVs, go-karts and motorcycles. In April, 2013, Kandi completed an EV assembly line with initial annual production capacity of 100,000 vehicles. Kandi has increasingly gotten official sanction of its low-speed EV strategy, and is working with a number of cities to establish what it

[48] Reuters. "Rural Chinese Flock to Tiny Electric Cars." The New York Times, April 19, 2012, sec. Business Day / Global Business. http://www.nytimes.com/2012/04/20/business/global/rural-chinese-flock-to-tiny-electric-cars.html.

[49] King, Danny. 2012. "Kandi EV gets 20,000 orders in Hangzhou, China." AutoblogGreen, July 18. http://green.autoblog.com/2012/07/18/kandi-ev-gets-20-000-orders-in-chinese-city/

[50] Whiteley, Patrick and Wang Chao. 2011. "China wants to be global leader in electric vehicles." *China Daily USA.* May 19. http://usa.chinadaily.com.cn/epaper/2011-05/19/content_12539963.htm

[51] Perkowski, Jack. 2013. "The Reality of Electric Cars in China." Forbes. June 24. http://www.forbes.com/sites/jackperkowski/2013/06/24/the-reality-of-electric-cars-in-china/

terms "mini-public transportation EV sharing systems."[52]

Central and local governments have organized policies and resources around conventional EVs. For example, all subsidies have range requirements that effectively exclude low-speed EVs. Further, central government regulations on what constitutes a "highway capable" vehicle (speed of at least 80 km/hr and a range of 80 km) have stymied the growth of the low-speed EV market. Some stakeholders have argued that these rules should be relaxed. A 2013 estimate by Guo Konghui, of the Chinese Academy of Engineering, found that if permitted on highways, half a million low-speed EVs could be sold within three years.[53]

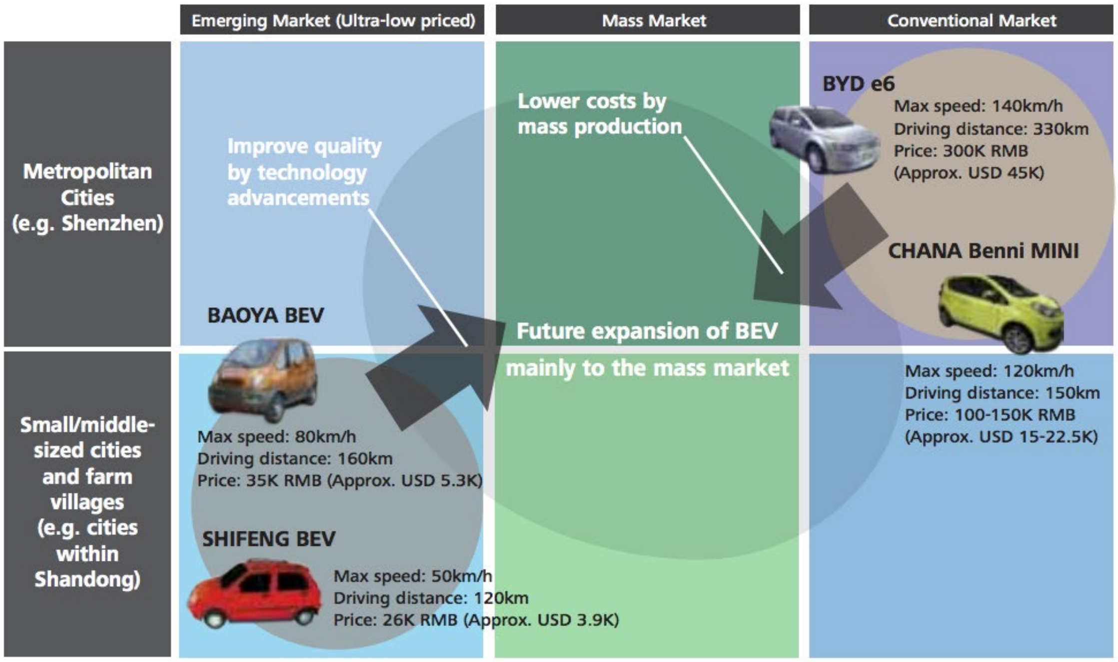
In 2013, the NDRC designated Shandong province a low-speed EV test zone. Shandong, home to Shi Feng among others, has quietly become a major center of low-speed EV manufacturing. The province produced over 86,000 low speed EVs in 2012.[54] With only little help from the central government, low speed EVs could nonetheless become the foundation of China's EV industry. Figure 4 describes the role that this potentially disruptive technology could have in forming a mass market for EVs. They can force the makers of conventional vehicle substitutes to focus on reducing price, and generate a meet-in-the-middle result on cost and performance.

52 Yahoo Finance. 2013. "Kandi Technologies announces Chinese government issued 2013-2015 subsidy policy for new energy vehicles." Globe Newswire. September 19. http://finance.yahoo.com/news/kandi-technologies-announces-chinese-government-120500141.html. These vehicles are not highway compatible.

53 ChinaAutoWeb. 2013. "Kandi and Geely team up to promote short-range EVs." March 24. http://chinaautoweb.com/2013/03/kandi-and-geely-team-up-to-promote-short-range-evs/

54 Shanghai Metals Market. 2013. "Low speed electric vehicles attract RMB 15 billion in investment, future hinges on policy." July 9. Available at http://www.metal.com/newscontent/50926_low-speed-electric-vehicles-attract-rmb-15-billion-in-investment-future-hinges-on-policy

Figure 4. Potential Market Development from Low-speed and Conventional EVs[55]



Even further down the food chain, electric bikes (ebikes) are an even larger and better-established market in China. Regulations banning gas-powered scooters in some Chinese municipalities provided a massive boost to demand, giving ebike companies an edge on foreign competition.[56] About 90 per cent of the world's electric vehicles are made in China, mainly for the domestic market. China already has about 120 million ebikes on the road. Compared to the conventional alternative, ebikes present a value proposition that has thus far eluded EVs: ebikes cost less and go farther than gasoline-powered scooters. [57] In 2012, standard ebikes cost only ¥1,000-2,500, often with maximum speeds as low as 20 km/hr.[58] Some scholars, like Wang Tao at the Carnegie-Tsinghua Center for Global Policy, have argued that this success in ebikes is a reason China has a major advantage when it comes to deploying EVs, and that the ebike industry can be replicated in China's large auto manufacturing sector. [59]

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55 Lei Zhou et al. 2010. "Charging Ahead: Battery Electric Vehicles and the Transformation of an Industry." Deloitte Review, Issue 7.

56 Masson, Laurent. "Chinese Vehicle Makers Arrive, With Electric Cars Not Far Behind | PluginCars.com", n.d. http://www.plugincars.com/chinese-electric-cars-chinese-manufacturers-are-here-112870.html.

57 Wang Tao. 2013. "Recharging China's electric vehicle policy." Carnegie Tsinghua Center for Global Policy, Policy Outlook, August 2013.

58 Wang, H., & Kimble, C. (2012). The Low Speed Electric Vehicle–China's Unique Sustainable Automotive Technology?. In *Sustainable Automotive Technologies 2012* (pp. 207-214). Springer Berlin Heidelberg.

59 Wang Tao. 2013. "Recharging China's electric vehicle policy." Carnegie Tsinghua Center for Global Policy, Policy Outlook, August 2013.

IV. Charging Infrastructure

One of the challenges to EV deployment is the chicken-and-egg problem of who is willing to construct charging stations when there are no EVs on the road, or who is willing to buy an EV without any charging stations available. Electric utilities or transmission operators must be involved in charging infrastructure development, but in theory third parties or automakers can supply charging equipment, as companies in Japan and the U.S. have attempted.

To provide a bit of background, there are three basic EV charging systems: AC (slow) charging, DC (fast) charging, and swappable batteries. For the first two, the size of the battery determines how much electricity is needed to bring it from depleted to full charge. The Nissan Leaf, for example, has a 24 kWh battery, while the BYD e6 has a 60 kWh battery. The amount of time it takes to charge depends on the voltage (pressure) and amperage (current). Multiplying voltage and amperage equals watts, the measure of power. The charging station has a maximum capacity in kW at which power can transfer. Hence, a charge with a capacity of 3kW can theoretically charge a 24 kWh batter in 8 hours. Most EV batteries cannot be completely depleted or filled. For example, when a 24 kWh battery is repowered, only about 18 kWh is actually charged, so the actual time for the recharging would be close to 6 hours.

Slow chargers have power rates between 1 and 2 kW. Using a household 110 (or 120) volt outlet, a slow charger will take about 20 hours to charge a Nissan leaf (BEV) or about seven hours to charge a PHEV, such as a Chevy Volt.[60] To increase the rate, 220 (or 240) volt systems can be used, which will half the charging times. Both these systems are common in the United States which relies heavily on localized decentralized charging systems.

The second option is to develop and deploy fast charging equipment able to recharge an EV battery in approximately the same time it takes to fill a conventional car with gasoline. These level III chargers draw between 100-200 kilowatts –as much as 140 homes. Tesla is marketing a supercharger which is close to meeting this goal and other new technologies are close to commercialization. There are several problems with this option. First, such stations must meet very strict safety standards, and these standards would have to be strictly enforced by the government to prevent serious accidents. Second, the surge demand and the voltage requirements for such a station would be substantial.

The third option is to swap out the batteries, replacing the depleted battery with a charged one in about the same time required to refuel a conventional car. In this model, the car owner buys the vehicle without the battery, dramatically reducing the price of the vehicle. The driver leases the battery from a third party, which also owns the swapping stations. Stations must own about 1.5 batteries for every vehicle that uses its facility. These batteries are very expensive and thus the upfront costs of these facilities can be substantial. To recover their capital and operating costs, these centralized facilities charge a user fee – either on a monthly or a per visit basis. In the case of battery swapping, the fee is usually in the form of a monthly lease payment for the battery. These fees, if not subsidized, can be quite high.

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60 Lee and Lovellette, 2011. Will Electric Cars Transform the U.S. Vehicle Market? An Analysis of the Key Determinates. Belfer Center Discussion Paper. July 2011.

In China, two state-owned companies, the State Grid Corporation of China (SGCC) and China Southern Power Grid (CSPG) have a monopoly on the country's electric transmission system and the power grid in their respective regions. Both companies place a high priority on meeting centrally issued mandates for renewable energy integration and improved reliability. They have been asked to foot the bill for EV charging stations, but without large numbers of EV vehicles on the road there is no obvious business model.

According to SGCC, they built 383 charging stations and battery-swapping stations by June 2013. These contained 15,444 AC charging plugs.[61] This is only 16 percent of the 2,351 stations (containing 220,000 plugs) they committed to build during the 12th 5 Year Plan (2011-15). [62] Through the end of 2012, CSG built only 18 stations, with 3,229 AC charging plugs.[63]

One reason for the reticence may be that EVs would place pressure on China's already strained grid. It is not clear that the electricity system can handle anything close to China's targeted EV deployment. A 2011 study found that U.S. and European electric grids are better equipped than the Chinese grid to handle significant numbers of EVs. If 5% of all households in China had EVs, and they all charged at the same time with only Level 2 chargers at 4 kW, they would use 13.2% of the State Grid's peak load capacity, and 12.1% of CSPG's peak capacity. Fast Level 3 chargers at 20 kW would take a staggering 65.8% and 60.4%, respectively.[64]

While the CSG has moved slowly to contract new charging stations, both grid companies have insisted on retaining control over the future charging network and being the primary network builders and standard-setters. They appear to have enough political clout to occupy the precarious position of not making big investments, while simultaneously claiming exclusive monopoly rights to make those investments. However, recently other players – including automakers, foreign firms, and the national oil companies – have begun to enter this space and challenge the two grid operators.

Whether to focus on battery swapping or on charging stations has become a contentious issue, with the grid companies on one side and the automakers and oil companies on the other. Liu Zhenya, General Manager of SGCC, at a 2011 conference on charging facilities, made a strong case for the superiority of the swapping model, including the argument that consumers would find EVs too expensive if they had to buy the battery as part of the up front price.[65] He concluded that

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61 State Grid Corporation of China. 2013. "EV infrastructure and standardization in China." Presentation. October 2013.

62 Wang Rong (王荣). 2011. "National Grid plans to spend 20 billion yuan to build electric charging infrastructure (*guojia dianwang ni tou 200 yi yuan jian diandong qiche chun dian sheshi*国家电网拟投200亿元建电动汽车充电设施." International Power Grid (*guoji dianliwang*国际电力网.) December 30, http://power.in-en.com/html/power-08570857181243043.html

63 State Grid Corporation of China. 2013. "EV infrastructure and standardization in China." Presentation. October 2013.

64 Green II, R.C., L. Wang, and M. Alam, "The impact of plug-in hybrid electric vehicles on distribution networks: A review and outlook," Renewable and Sustainable Energy Reviews 15:544–553, January 2011.

65 Wang Rong (王荣). 2011. "National Grid plans to spend 20 billion yuan to build electric charging infrastructure (guojia dianwang ni tou 200 yi yuan jian diandong qiche chun dian sheshi国家电网拟投200亿元建电动汽车充电设施." International Power Grid (guoji dianliwang国际电力网.) December 30, http://power.in-en.com/html/power-08570857181243043.html

SGCC viewed the swapping stations as the "primary" infrastructure and the charging stations as "secondary."[66]

The automobile industry, however, is not enthused about dividing ownership of the battery and the vehicle and is worried about the liability and safety implications. Vehicle manufacturers have argued that battery swapping is unsafe because there is currently no unified technological standard for batteries, creating the potential for the swapping stations to insert a battery that is incompatible with the car. Building all EVs to meet the specifications required by the stations places a level of coordination onus on the automakers with which they are not comfortable. Instead the automakers are working with the oil industry, specifically, PetroChina and Sinopec, to build EV charging poles adjacent to existing gas stations.[67]

Regardless of how this debate resolves, China has started down a path of relying on large centralized charging stations as opposed to the decentralized model favored in the United States and Europe. It has so far built large stations with multiple charging poles, which is quite different from the 1-4 plug stations that are standard elsewhere. In part due to scale, and in part due to lower land and labor costs, China may have an advantage in installation costs compared to other countries. For a Level 3 DC fast charger, an initial capital cost assessment for China found that stations cost only $6,000 to build in China, compared to $30,000 the U.S., and $50,000 in the EU.[68] Stations will have multiple fast charges and this figure does not include land costs, which will fluctuate depending on whether rights to the land is publicly provided or purchased privately.

China's focus on fleet vehicles and more recently its decision to focus its subsidies to promote EVs in specific urban regions reduces the demand uncertainty that confronts investments in charging stations in the U.S. However the ownership debate is likely to remain. Does China want to give its two monopoly grid companies exclusive rights to build these central facilities or does it want to encourage other companies to offer competitive services? The centralized model emphasizes economies of scale and therefore may raise barriers to entry for smaller, non-state owned enterprises. If the market remains a monopoly, it will require tight regulation. This is to be expected in the near term given that electricity prices are currently set by the Chinese central government. If China moves to liberalize wholesale electricity prices, it will be important to ensure that charging infrastructure is not subject to market abuses.

66 Ibid.
67 Xu, Lihui and Jochen Alleyne. 2012. "Charging or changing: The question for China's electric vehicle market." SGT Insights, SGT Research SmartGrid Times and Consulting. February 20.
68 Li, Z. and M. Oouyyang, "The pricing of charging for electric vehicles in China -- Dilemma and solution," Energy 36:5765-5778, September 2011. Note: Exchange rate of Y1 =$0.16 used.

Figure 5: The world's first ultrafast charging station in Chongqing, 2012[69]

Battery Innovation

Today Korean company LG Chem is the global leader in batteries for BEVs and HEVs. According to a 2013 Navigant research report ranking EV battery vendors by a complex set of technology and sales metrics, only one Chinese firm, BYD was included in the top ten (and was in 10th place).[70] Of the other nine, five are Japanese, three Korean, and one American.

Although it is hard to gain precise figures, the economics of battery manufacturing may not be very sensitive to location. Boston Consulting Group estimates that compared with South Korea, costs in the US would only be 6% higher, and costs in China only 8% lower.[71] This is largely a result of the low labor content in final costs. Thus the scope for Chinese firms to drive battery costs far below their competitors may be limited. The average new car is much cheaper in China than in the U.S. or Europe. Therefore, stubbornly high battery costs are a greater obstacle to EV deployment in China than elsewhere because batteries are a higher proportion of the total costs of new EV vehicles. Battery costs are a 'floor' preventing EVs from competing on price with conventional vehicles.

However, China is better positioned to take a leadership role in batteries than in final EVs. The primary Chinese firms producing EV batteries are BYD, Lishen, BAK, Shenzhen Desay Battery Technology, Wanxiang Group, and Shanghai Fuel Cell Vehicle Powertrain. All received 863 Program R&D support. Many have the advantage of a large established supply chain for consumer electronics batteries. BYD is trying to use an iron-phosphate battery instead of li-ion. This chemistry is apparently cheaper and more stable, making it, in theory, safer. However, iron-phosphate has lower energy density. BYD is therefore gambling on urban driving, where short distances and slow speeds will allow these batteries to perform well.

Wanxiang group is increasingly multinational, with offices and hundreds of employees in Illinois, having purchased a number of U.S. high-tech firms in recent years. Most prominently, in 2013 Wanxiang bought the assets of bankrupt A123 Battery, an American firm whose technology was born at MIT. SAIC uses A123 batteries in its Roewe E50. [72]

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69 China Auto Industry News. 2012. "Microvast announces commercial operation of ultra-fast charging station in Chongqing." China Car Times, June 12. http://www.chinacartimes.com/2012/06/microvast-announces-commercial-operation-ultra-fast-charging-station-chongqing/

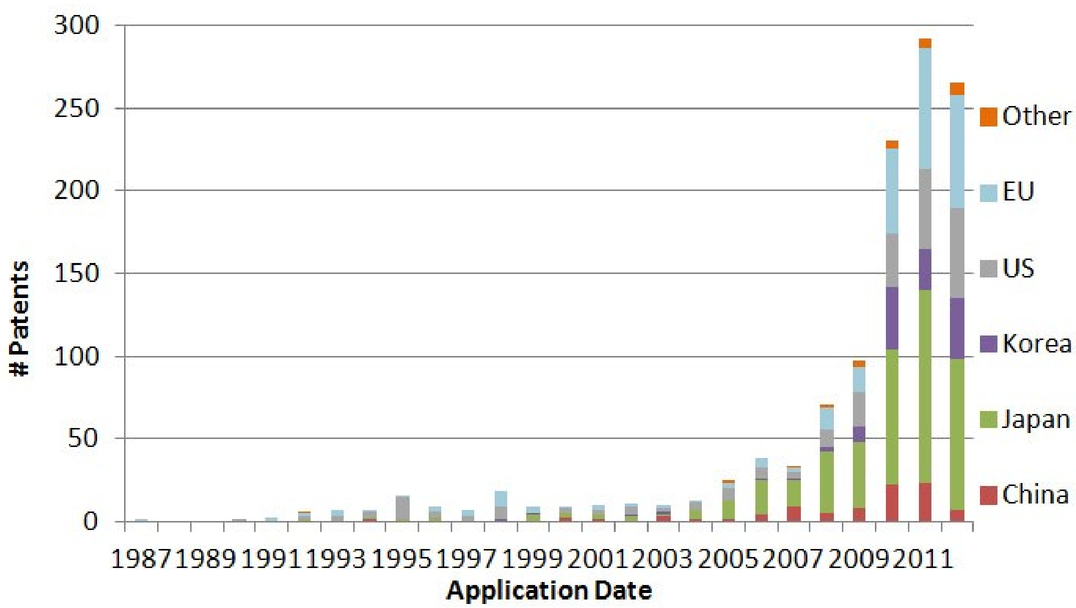
70 Navigant Research. 2013. "Lithium ion batteries for electric vehicles. " Leaderboard Report.

71 Boston Consulting Group. 2010. "Batteries for Electric Cars, Challenges Opportunities and the Outlook to 2020." BCG Insights.

72 Vlasic, Bill. 2013. "Chinese creating new auto niche within Detroit." *The New York Times.* May 12.

At home, China is investing in substantial advanced battery research, some of it in promising joint projects between universities, automakers and battery manufacturers.[73] Between 1998 and 2007, China filed just 1% of patent registrations for li-ion batteries, against Japan's 52% and the U.S.' 22%.[74] However, more recent statistics paint a somewhat brighter picture. In a company ranking of 2010 electric vehicle-related patent applications to the US Patent and Trademark Office, Chery ranked 9th with 17 applications and BYD ranked 19th with 11 applications.[75]

Figure 6: Successful International Patents (PCT) Relating to EVs by Country[76]



Rare-earth metals are needed for lithium-ion batteries, permanent magnet motors and other key components of EVs. China's most recent 5-Year Plan suggested that rare earth (e.g. lithium) resources are a strategic advantage for EV development. However, as the environmental damage from toxic mining has become more salient, this view is changing.[77] Indeed, China's rare earth bounty has become an environmental and trade liability. In 2006, China imposed taxes and tonnage limits on rare earth exports. The price of rare earths skyrocketed, and other countries filed suits with the WTO. In 2010, China continued to produce 95% of the world's rare earths.

Yet rare earths are not actually that rare: as new mines have opened up in other countries, dropping China's production to 85% in 2012 and this percentage is expected to fall still further. Another perspective is that other countries with rare earth resources, like Australia and the U.S., have

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73 Earley, Robert et al. 2011. "Electric vehicles in the context of sustainable development in China." United Nations Department of Economic and Social Affairs and Innovation Center for Energy and Transportation. Background Paper No 9.

74 Japan Ministry for Economics, Trade and Industry (METI). 2009. "Patent Trend Report: Lithium Ion Battery."

75 Girling, Authur. 2011. "Who owns electric vehicle technology?" *Cleantech Magazine,* February.

76 World Intellectual Property Organization. Patenscope, accessed July 2013. http://patentscope.wipo.int/search/en/search.jsf

77 Ministry of Science and Technology (*zhonghua renmin gongheguo kexue jixu bu* 中华人民共和国科学技术部). 2011. "Electric vehicle technology development specific 12th Five Year Plan (*diandong qiche keji fazhan shi er wu zhuanxiang guihua* 电动汽车科技发展"十二五"专项规划)." http://www.most.gov.cn/tztg/201204/W020120503407413903488.pdf

outsourced the toxic job of mining it to China.[78] In that light, China's dominance of global mining appears less of an advantage.

V. Can EVs Compete with Conventional Vehicles in China?

Historically, most of the EVs that China has deployed have been purchased by the government for public fleets, and have been heavily subsidized. Subsidies cannot continue indefinitely – eventually EVs must become competitive with conventionally powered vehicles.

Ultimately, broad deployment of EVs in China will depend primarily on three factors:

1. The costs of EV ownership relative to comparable conventional vehicles, including:
    a) Vehicle purchase price without subsidies
    b) Gasoline and electricity cost
2. Relevant differences between EV and conventional vehicles (e.g. range, safety, and style)
3. Availability of adequate charging infrastructure

Vehicle Costs

In the previous section, we discussed the challenges of establishing adequate charging infrastructure. In this section, we turn our attention to the costs of EVs and to a comparison of their attributes with those of conventional vehicles.

Batteries represent the largest single additional cost for EVs. Future affordability will thus depend on the ability of battery producers to reduce costs. Today, in China, BEVs are still far from competitive with conventional vehicles in terms of purchasing price, even when subsidies are included. For example, in Shenzhen, where consumers can access the central government subsidy of ¥60,000 as well as a city-level additional ¥60,000 subsidy, the price of a BYD E6 is still ¥170,000-180,000, which is twice the price of similar, domestically branded conventional vehicles. The major reason is the cost of the battery.

Battery costs are usually measured in kWh of storage capacity. This metric determines the range of the vehicle between charges, conditional on weight, load, aerodynamics, and driving conditions. Getting to a lower per kWh battery cost is absolutely critical to the future of the EV industry. Automakers are not terribly transparent about their battery costs, but current costs are likely around $700/kWh, making the 24 kWh Nissan Leaf battery around $16,800, which is almost twice the cost of basic compact domestically branded cars in China.

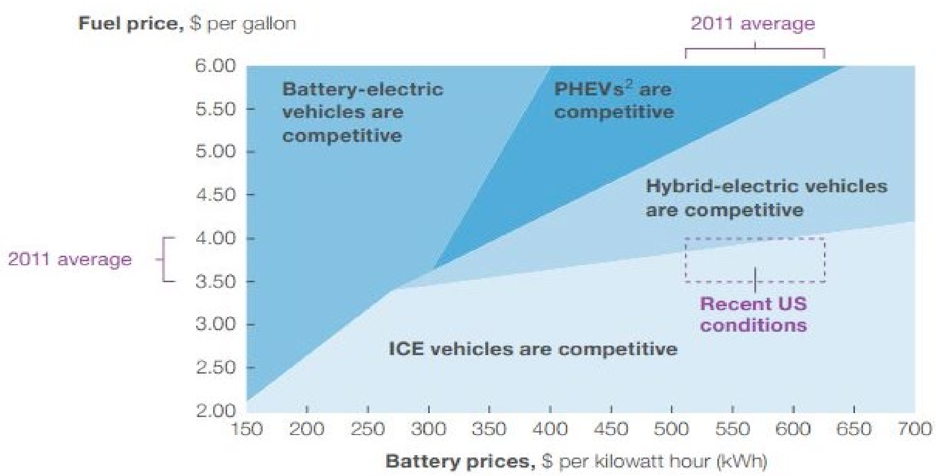
Unfortunately, it appears that there is no Moore's Law for EV batteries – that is, a doubling of performance for the same cost every two years. Unlike electrons, ions (which transfer power in batteries) take up space, as do the anodes, cathodes and electrolytes that make the transfer possible.

78 Martyn, Paul. 2012. "Rare earth minerals: An end to China's monopoly is in sight." *Forbes,* June 8.

Ultimately, new chemistries will be required to dramatically increase battery performance.

In April 2012, Bloomberg New Energy Finance (BNEF) estimated that the average price for a li-ion battery pack was $689/kWh, based on EVs such as the Mitsubishi Motor iMiEV, Nissan Leaf and Tesla Model S. This is 14% below 2011 costs of $800/kWh, and 30% below 2009, when the packs cost more than $1000/kWh. [79] In a different report, BNEF's reported prices had fallen further to $599/kWh at the end of June 2013. "Our view is that recent price reductions are very significant, and part of the reason is due to the severe overcapacity in the market at the moment."[80] By February 2014, reports cited battery costs of $500/kWh.[81] The Chinese government's targets in the Energy Saving and New Energy Vehicle Industry Development Plan, are 2000 yuan ($310) per kWh by 2015 and 1,500 yuan ($160) by 2020. With sufficient production scale, the first of these goals is not impossible. However, given China's current production capability, the goals are likely aspirational.

Figure 7: EV Competitiveness with Conventional ICE Vehicles[82]



Gasoline Costs

While the principal disadvantage of EVs is high initial capital costs, their principal advantage is much lower operating costs. Electricity prices will increase over the next few decades, but they will remain low compared to gasoline. Fuel prices in China have risen over the past decade, reflecting both rising global market prices and reductions in subsidies. The NDRC sets gasoline prices, but has in recent years steadily moved toward allowing retail prices to adjust with the market.

In recent years China's gasoline price has been between 120 -150% of US prices because China

[79] Bloomberg New Energy Finance. 2012. "Electric vehicle battery prices down 14% year on year." April 16. http://www.bnef.com/PressReleases/view/210

[80] Marshall, Jonathan. 2013. "Are cheap batteries around the corner for electric vehicles?" July 18. PG&E Currents. http://www.pgecurrents.com/2013/07/18/are-cheap-batteries-around-the-corner-for-electric-vehicles/

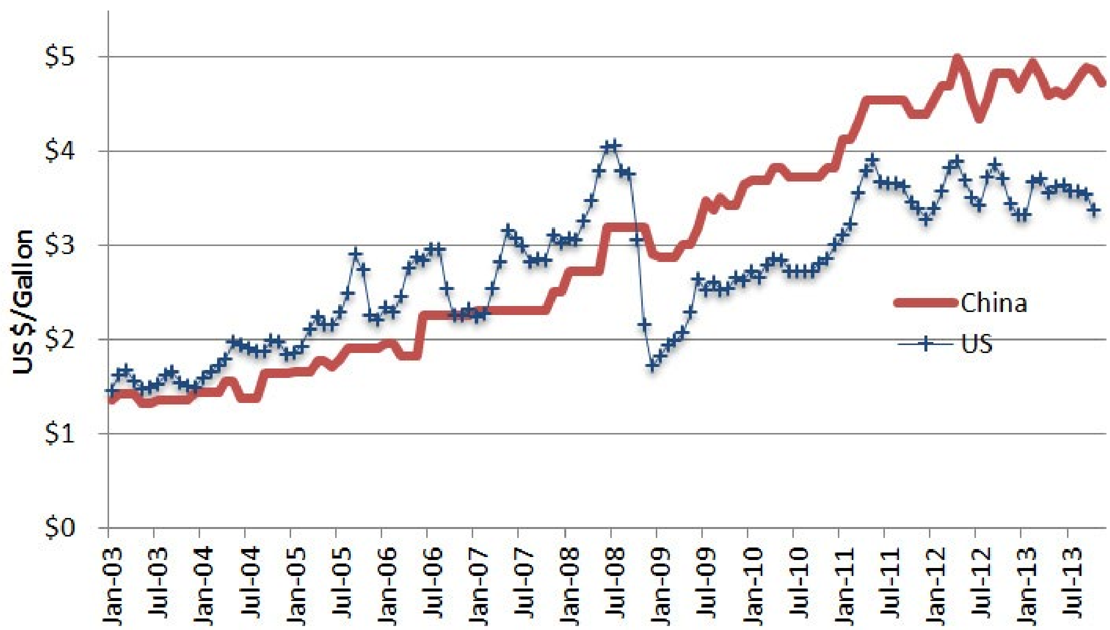
[81] Singh, Sarwant. 2014. "Elon Musk's 500,000 unit battery plant: Myth or reality?" *Forbes,* February 27.

[82] Competitiveness is measured on a total cost of ownership basis, and this assumes 240 watt-hours per mile, rather than today's 305-322 watt-hours per mile, requiring somewhat lighter weight cars and efficient AC. Hensley, Russell et al. 2012. "Battery technology charges ahead." *McKinsey Quarterly.* July.

has higher fuel taxes. At the end of August, 2013, NDRC set the retail ceiling price (retailers can charge less, but not more) for 90-octane gasoline (though most retailers sell higher grades) at ¥9,505 per ton, which translates to $4.78/gallon at current exchange rates. The next change came at the end of September, 2013, when the NDRC announced that starting October 30, the price would be reduced to about $4.66/gallon.

These gasoline prices are significantly higher than in the U.S. and will favor the comparative costs of EVs over their lifetime (combining capital and operating costs). The higher the price of gasoline, the more favorable the operating cost advantage for EVs. The payback period (the time it takes for lower operating costs to make up for the high capital costs) is shorter for cars that have higher annual mileage.

Figure 8: Retail Gasoline Prices, China & US (Monthly $/gall at contemporary exchange rates)[83]



Future gasoline prices are, of course, uncertain. Increases in transportation and energy use as a result of growth in emerging markets are expected by some to keep demand high over the next two decades. However, recent increases in the availability and production of non-conventional oil resources, not least in the United States, means that there will be more supply than anticipated only a few years ago. The World Bank July 2013 commodities futures forecast expects oil prices to be $98 per barrel in 2020. Yet their report from a year earlier forecast 2020 prices at $108/bbl.[84] Other

83 Constructed by authors using data from: Source: Energy Information Administration. 2013. "Weekly U.S. All Grades Conventional Retail Gasoline Prices." http://tonto.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMM_EPM0U_PTE_NUS_DPG&f=M

Reuters. 2012. "TABLE-China retail gasoline, diesel prices since 2003." http://www.reuters.com/article/2012/06/08/china-fuel-prices-idUSL4E8H87D720120608. Reuters. 2012. "TABLE-China retail gasoline, diesel prices since 2009." http://www.reuters.com/article/2013/08/30/china-fuel-prices-idUSL4N0GV29720130830

84 World Bank. 2013. "Commodity Price Forecast Update." July 8. http://siteresources.worldbank.org/INTPROSPECTS/Resources/334934-1304428586133/Price_Forecast_July2013.pdf

experts, though, are predicting 2020 prices in the $75 per barrel range.[85]

The prices that Chinese consumers pay for fuel will also depend on the tax and regulatory regime. However, the fact that consumers cannot count on these prices is itself problematic. Oil markets are volatile, creating consumer uncertainty about future oil prices, which can have negative impacts on their willingness to purchase fuel efficient vehicles or EVs.

Electricity

Historically there was little local variation in power prices in China. Currently, residential consumers are charged around ¥0.4 ($0.08) per kWh. Commercial customers pay double: ¥1 ($0.16) per kWh. This compares with national residential prices in the U.S. that have been about $0.12 per kWh in 2013.[86] However, China has recently allowed some provinces to establish new pricing systems in order to mitigate ballooning demand and absorb the higher costs of domestic coal. Most tariff systems have different tiers based on use, so that households using little electricity pay a low rate, but those that use more than 400 kWh per month, pay a higher one.[87]

In China, EV charging prices are not now subject to the national prices and are instead set by local governments and grid companies. However, grid companies can offer lower prices for off-peak charging. Shenzhen is offering nighttime charging for only ¥0.3 ($0.05) per kWh. Electricity prices are unlikely to be a barrier to EV penetration.

Consumer discount factors and perceptions

Money in the future is worth less to a consumer than that same money today. How much less – the discount rate – is critical to comparing EV and conventional vehicle costs. EVs have higher upfront costs, but at some point their lower operating costs will provide additional savings. If consumers have high discount rates, then EVs are a much harder sell, and battery-leasing or car rental models become slightly more viable.

Historically, consumers have seemed reluctant to make apparently high-return investments in the energy efficiency of appliances, vehicles and other durable goods. Termed the "Energy Paradox" by Jaffe and Stavins (1994), consumers appear to undervalue or ignore future fuel costs when buying vehicles. This phenomenon has been well studied in the U.S., and is a key rationale for policies like the U.S. fuel economy standards.[88] If consumers are insensitive to higher gasoline prices when purchasing a vehicle, then a gasoline tax will not have a large impact on consumer choice, though it may impact driving patterns.

Estimates of fuel economy regulations sometimes result in *negative* private costs, even using discount rates of 7%.[89] The explanation for why automakers don't build more efficient vehicles relies on the "misperceptions" hypothesis, in which consumers are myopic, unable to calculate future

85 Maugeri, Leonardo. 2012. "Oil: The Next Revolution." Discussion Paper 2012-10, Belfer Center for Science and International Affairs, Harvard Kennedy School, June.

86 EIA Electric Power Monthly, http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_3

87 Xinhua. 2012. "China implements new electricity prices." China Daily, July 2.

88 Jaffe, Adam, and Robert Stavins (1994). "The Energy Paradox and the Di§usion of Conservation Technology." Resource and Energy Economics, Vol. 16, pages 91-122.

89 National Highway Traffic Safety Administration. 2010. "Final regulatory impact analysis, corporate average fuel economy for MY 2012–MY 2016 passenger cars and light trucks." U.S. Department of Transportation.

benefits, or are misinformed. Skeptics of this approach point to numerous unmeasured costs associated with new technologies, uncertainty over future oil prices, and competing vehicle attributes. These can increase the implied discount rate and add further costs.[90]

Empirical studies of consumer willingness to pay for fuel economy range widely, but recent estimates that use the relationship between vehicle and gasoline prices over time find implied private discount rates between 6% and 21%.[91] U.S. consumers have traditionally put a high discount rate on energy savings due to three factors: 1) uncertainty over future fuel prices; 2) uncertainty on how long they intend to keep the vehicle; and 3) uncertainty about future economic events that would affect the value of their purchase. One rule of thumb used by manufacturers is that consumers require a fuel economy payback of around 3 years, rather than the vehicle expected lifetime. There has not been much study of Chinese consumer discount rates. The CLASP model for analyzing energy efficiency standards impacts uses a 9.7% consumer discount rate for China, based on World Bank data and therefore we use a 10% rate in our calculations.[92] However, we suspect that this figure is too low, and might bias our calculations in favor of electric vehicles.

To illustrate the significance of the factors described above, we employ a simple model describing the potential effects of gasoline prices, battery costs, and discount rates on the competitiveness of Chinese EVs and PHEVs.[93] Specifically we compare the net present value of a conventional vehicle (the BYD F3), a plug in hybrid electric vehicle (the BYD QIN), and a battery electric vehicle (BYD E6). We compare vehicles over their life cycle, incorporating both capital and operating costs.

Since we do not have cost data on several factors for China, we simplify the model from its original version in Lee and Lovellete (2011). For example, we make rough estimates on transmission and inverter costs. Importantly, we assume BEVs will either be charged at central stations or will be part of a battery exchange program (BEVs only). We only include the electricity cost of the charge and not the fee that will be required to use the central stations. We simply could not find credible estimates.

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90 Anderson, Soren T. et al. 2011. "Automobile fuel economy standards: Impacts, efficiency and alternatives." *Review of Environmental Economics and Policy.* Vol 5, issue 1.

91 Allcott and Wozny (2012) find 15%; Busse, Knittel, and Zettelmeyer (2012) find a range depending on assumptions between 6.2% and 21%; Dreyfus and Viscusi (1995) find 11%-17%, On the other hand, Espey and Nair (2005) find consumers overvalue fuel economy, leaving an implied discount rate of 1%. Sources: Busse, M. R., Knittel, C. R., & Zettelmeyer, F. (2013). Are Consumers Myopic? Evidence from New and Used Car Purchases. *The American Economic Review*, *103*(1), 220-256.

Dreyfus, Mark, and Kip Viscusi (1995). "Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency." Journal of Law and Economics, Vol. 38, No. 1, pages 79-98. Espey, M., and S. Nair (2005). "Automobile Fuel Economy: What is it Worth?" Contemporary Economic Policy 23(3): 317-323.

92 Collaborative Labeling & Appliance Standards Program (CLASP). Policy Analysis Modeling System. http://www.clasponline.org/en/Tools/Tools/PolicyAnalysisModelingSystem

93 Lee and Lovellette, 2011. Will Electric Cars Transform the U.S. Vehicle Market? An Analysis of the Key Determinates. Belfer Center Discussion Paper. July 2011.

The cost of the 2014 BYD E6 – our sample EV – is ¥322,400 ($52,000). To generously account for coming price reductions and expected discounts at the dealership level, we have set the price in our calculations to ¥250,000. For a BYD QIN – our sample PHEV – the price is ¥191,000 ($31,006). Small conventional vehicles in China are very inexpensive compared to vehicles in the U.S. The BYD F3 costs only ¥59,800 ($15,835). If we assume payments over the lifetime of the vehicle, gasoline prices of $4.60 per gallon (actual price December 2013), battery pack cost of $600, and a discount rate of 10%, the conventional vehicle is substantially less expensive (see Table 3).[94] (See Appendix D for a list of additional assumptions.)

Table 3. Base Case - under 10% Discount Rate

	Conventional	PHEV	BEV
Total Net Present Cost	$25,403	$39,781	$44,383
Cost Differential with Conventional Vehicle		$14,377	$18,980

In five of China's most populous regions, both the central and local government offer very generous subsidies for both BEVs and PHEVs. The central government subsidies are ¥60,000 for a BEV and ¥50,000 for a PHEV, and the city or local subsidies are ¥60,000 and ¥30,000 respectively. It is important to remember that there is no guarantee that these same subsidies will be available in future years and that these subsidies are only available in certain regions. However, with very generous subsidies, BEVs are competitive with conventional vehicles, but PHEVs remain slightly more expensive over their lifetime (see Table 4).

Table 4. Base Case with Central and Local Subsidies

	Conventional	PHEV	BEV
Total Net Present Cost	$25,403	$26,981	$25,183
Cost Differential with Conventional Vehicle		$1,577	($220)

If battery costs fall from $600 per KWH to $300 per KWH, the cost differential between conventional vehicles and BEVs falls from $18,980 to $11,572. Even under this scenario, BEVs are uncompetitive without subsidies. However, if you add the present subsidies, both PHEVs and BEVs become very competitive (see Table 5). In our final specification, we increase gasoline prices from $4.60 per gallon to $5.60 per gallon, keep battery costs at $600 per kWh, and maintain the subsidies (see Table 6).

94 A 10% discount rate is very low – the actual rate is probably closer to 18%. A low rate will favor BEVs.

Table 5. Subsidies Plus $300 per KWH Battery Costs

	Conventional	PHEV	BEV
Total Net Present Cost	$25,403	$22,878	$17,776
Cost Differential with Conventional Vehicle		($2,525)	($7,628)

Table 6. Higher Gasoline Prices with Subsidies

	Conventional	PHEV	BEV
Total Net Present Cost	$27,510	$27,182	$25,183
Cost Differential with Conventional Vehicle		$328	$2,327

These calculations suggest that without very generous subsidies, EVs will have difficulty competing with conventional vehicles under almost any scenario. In the future, the price of conventional vehicles may rise, battery costs may decrease, and gasoline prices go up. However unless these changes are substantially greater than anticipated, BEVs will have difficulty competing without government assistance. For example, battery prices would have to fall significantly below the $200 per KWH target and gasoline prices reach over $12 per gallon for BEVs to be competitive without subsidies. These numbers decrease slightly if local subsidies are removed, but central subsidies remain (battery cost of $220 per KWH and gasoline price of $9.05 per gallon).

VI. Challenges to Electric Vehicles Deployment in China

In other energy areas, particularly wind and solar, and to a lesser extent shale gas, China has consistently met or exceeded government-set targets. Yet with EVs, this is not happening. There are five key unanswered questions which will shape the future of EVs in China:

1. Will China be able to eliminate local protectionism and consolidate its EV industry in order to develop the technologies required for high quality EVs?
2. Will China be able to reconcile its currently conflicting goals of technological upgrading through EVs and mass EV deployment?
3. Will China continue to focus on mid-sized and large sedans or will it readjust its focus to low-speed EVs and ebikes?
4. Will China expand its policy instruments to include market pull options that will complement its heavy reliance on government push policies?
5. Will environmental health concerns stemming from reliance on coal-fired power, especially in the North, affect China's EV goals?

In this final section, we will look at each.

1. **Protectionism and its Impact on Technology Development**

China's ten years of effort to achieve leadership of the global EV industry has not been very successful. Its auto industry lacks concentration and without concentration, it is very difficult to achieve the scale required for significant R&D advancement.

The central government recognizes this problem. But it is met with resistance from the local governments, which own or sponsor many of the smaller companies. To incentivize local officials in the early stages of China's "Opening and Reform," Deng Xiaoping allowed them to retain a portion of local SOE profits, rather than passing them on to Beijing. Essentially, this policy made capitalists out of provincial and municipal officials, giving them a direct stake in the local automakers. Officials from different jurisdictions now actively compete with each other.

Some regional automakers, like Chery (owned by the Anhui provincial government) and SAIC (owned by the Shanghai government) have been very successful in building up local parts supply chains. [95] However, these local empires have been toxic to EV development. Changchun buys exclusively from FAW, Beijing buys from FOTON and Shenzhen buys from BYD. According to a BYD official, "Beijing is impossible – not only is it very difficult for us to bring our NEVs

[95] Thun, Eric. 2006. *Changing Lanes in China.* New York: Cambridge University Press.

to Beijing, but BYD would not even be able to invest in building a plant in Beijing."[96] Local governments have conditioned NEV subsidies on using local parts and have essentially forbidden automakers from using non-local parts. As one might expect, many of the local companies produce parts that are of mixed quality. As Li Liwei, a national spokesman stated, "Every city wants to use locally produced vehicles for demonstration, even bus purchases try to rely on local producers."[97]

The deputy director of the Chinese Communist Party Central Committee's Economic Committee, former MIIT Minister Li Yizhong, is reported as believing that local protectionism does not only prevent competitive enterprises from growing larger and stronger, but also has serious drawbacks in that it leads to low-level, redundant efforts in different provinces.[98]

China's weak automotive sector cannot afford this type of politically motivated decentralized development. In a 2010 article on the "Ten Cities Thousand Vehicles" program Du Jidong argued that since "Auto companies lack indigenous innovation capability, so it will be necessary for government to lead the way in the market and solve the innovation deficiency, as well as permit more open competition."[99] The government seems to agree. MOST's 12th Five-Year Plan for Electric Vehicles admits:

> "Developing EVs in China will require solving many problems, not the least of which is that China is not competitive in the core technologies…the traditional vehicles and related industrial base is weak, suffering from inadequate investment, and remains behind in an increasingly competitive and higher-tech auto industry."[100]

2. Institutional Conflicts

The Chinese government's decision to pursue EVs is based on competing public policy priorities—enhancing the competiveness of domestic automakers, energy security, local pollution abatement, technology leapfrogging, and low carbon development. There are advocates in the government for each of these priorities. However, specific EV policies can rarely be in the service of all of them.

If the domestic auto industry is not structured to deliver the cutting edge new EV technology, China is left with two options—either obtain the new technologies from foreign firms or focus EV development on areas where the country may have a stronger competitive advantage.

At the national level, significant trade barriers prevent foreign EV technology from entering the Chinese market, where in theory they could exploit consumer-side subsidies to achieve EV

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96 Cheng Yanyan (陈妍妍). 2013. "Calls to remove local protection in order to improve new energy vehicles (*xin nengyuan qiche lihao xilai che qi huyu quchu difang baohu* 新能源汽车利好袭来 车企呼吁去除地方保护)." Securities Daily *(zhengquan ribao* 证券日报), July 7. http://www.nbd.com.cn/articles/2013-07-16/758543.html

97 Wang Haiyun (王海蕴). 2013. "Testing the new energy vehicle industry (x*in nengyuan qiche de chanye hua kaoyan*新能源汽车的产业化考验.)" State Council Development Research Center Financial Services Sector (*guowuyuan fazhan yanjiu zhongxin caijin jie*国务院发展研究中心 财经界). August 8.

98 Ibid.

99 Du Jidong (杜纪栋). 2010. "Ten Cities Thousand Vehicles: Accelerating China's Battery Electric Vehicle Market Development (*shi cheng qian liang: jiasu zhongguo chun diandong qiche chanye hua* 十城千辆：加速中国纯电动汽车产业化)." October 14, 2010. http://www.evtimes.cn/html/201105/26062.html

100 Ministry of Science and Technology (*zhonghua renmin gongheguo kexue jixu bu* 中华人民共和国科学技术部). 2011. "Electric vehicle technology development specific 12th Five Year Plan (*diandong qiche keji fazhan shi er wu zhuanxiang guihua* 电动汽车科技发展"十二五"专项规划)."

deployment at scale. Although China decreased tariffs and eliminated import quotas in the mid-2000s to meet WTO accession commitments, it still maintains a 25% import tariff on vehicles. Since 2009 extremely stringent trade barriers have been erected against foreign automakers in an effort to induce technology transfer and promote innovation among domestic firms. Examples include sales tax waivers and both central and local subsidies that only apply to domestic vehicles. Most damaging, the government requires that any automaker selling an NEV in China must demonstrate that a local firm has ownership over the IP needed to produce that vehicle.

All of these restrictions create strong incentives for foreign firms not to share with or transfer their technological expertise to Chinese firms. In a global interconnected marketplace in which international collaborations are common, China's EV industry has thus far been comparatively isolated. This makes it more difficult for Chinese companies to reach the cutting edge of innovation in this particular industry. Both long term technological development and near-term EV deployment likely require lower foreign trade barriers.

One of the realities of Chinese energy policy making is that any major policy requires consensus among many agencies. While agencies may own certain parts of a larger issue, rarely does it have sole jurisdiction. Hence almost every issue requires many months of interagency discussion and often the final policy reflects the priorities of multiple departments. For example, MIIT, which is responsible for permits, is an advocate for more efficient conventional fossil-fueled vehicles. MOST has been a fierce advocate for BEVs and is the implementing agency of the Ten Cities Thousand Vehicles program. The NDRC has been most interested in energy pricing and energy security, Finally the Ministry of Finance is the source of the generous subsidies for EV purchases.

A corollary to the issue of consensus is that few policy makers have access to good energy data. Offices that possess data are loathe to share the data with other departments whose cooperation is needed on a given policy. Too often policy makers are forced to rely on experience and logical judgment as opposed to statistics. This becomes a larger problem when evaluating the success or lack thereof of a particular problem and may result in failing programs sustaining themselves longer than would be justified if they were rigorously evaluated.

These conflicts often provide mixed messages to the automakers, local governments and private consumers, who see merit in waiting to better determine whether the government's commitment to the policy will be sustained or replaced by another set of priorities.

3. Market niches with lower technology barriers

China has focused on mid-sized and large sedans in their EV promotion policies, but its advantage may be in smaller, low speed vehicles. The case for EVs rests on lower operating costs, requiring consumers to be quite price sensitive. By pursuing a full-size car replacement strategy for EV development, China has ensured that the EVs on the market are very expensive, because they require a large battery to power the heavy vehicle. Chinese consumers who would care about lower operating costs are unlikely, or unable, to purchase an EV sedan costing between ¥100,000-¥370,000. However, these consumers might be interested in a low-speed EV, for ¥31,000-¥60,000.

The low-speed EV market evolved in part due to China's strength in electric bicycles (ebikes). China can probably deploy low-speed EVs at scale with far lower consumer subsidies than it currently uses for full size EVs. If the government can focus on building the infrastructure to support widespread low-speed EVs, it can potentially solve the chicken-and-egg problem. Mass deployment of low-speed EVs could build a constituency for EVs both in industry and among consumers, and the auto industry can then upgrade to larger cars.

In the U.S., average daily driving, excluding days of no driving, is 45 miles. In Spain it is 47, and in Germany 34. In Beijing a recent study found that the median daily miles driven is 22, and 95% of daily driving is below 62 miles. In China overall, 98% of drivers drive less than 100 miles.[101] This is relevant for EVs generally, but especially for low-speed EVs, which have a shorter range. The disparity between driving habits in the West and China is likely mimicked in other emerging markets. In general, low-speed EVs have a strong potential market not only in China, but also in many developing countries. This could be China's "ticket" to global EV leadership.

4. Market Incentives

To date China's focus has been on stimulating its automakers to invest in EV technologies with a goal of developing a global product. Further, local governments were given generous subsidies to purchase locally produced EVs. In other words, China decided to use the government procurement system to create a market. Not all 25 of the selected cities chose to take advantage of these subsidies and thus the regional focus was narrowed over time. There are only so many taxis, buses and sanitation trucks that these cities purchase each year and there is only so much funding that the Ministry of Finance is willing to make available, hence a market dependent on government procurement is going to be limited. If the goal is to "test" multiple generations of EV technologies, this strategy might work. But as we have shown the rate of innovation has not met expectations.

In order to stimulate private consumption of EVs, the government and the automakers must shift their approach. Generous subsidies for private consumers in some regions where there is a consumer base sufficiently wealthy to purchase mid –sized EV sedans may initially be successful. Yet this strategy is limited by the number of consumers able to afford these vehicles. If EVs are to meaningfully penetrate China's auto market, a more comprehensive portfolio of market pull options is necessary in addition to the supply side incentives.

China has measurably higher gasoline prices than those in the United States, and residential electricity prices are slightly lower. So the major obstacle to consumer acceptance is the upfront cost of the vehicle itself as compared with comparable conventional ICE vehicles. Thus, strategies that reduce the cost of buying and using EVs compared to ICE vehicles will begin to change the incentive structure. Options might include higher taxes on gasoline and diesel fuel, feebates, where a consumer purchasing an EV gets an annual rebate paid for by a tax on large less efficient vehicles, or special privileges such as convenient parking or access to special lanes on congested highways or streets closed to conventional traffic.

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[101] International Council on Clean Transportation (ICCT). 2013. "Electric Vehicle Grid Integration in the U.S., Europe and China." July.

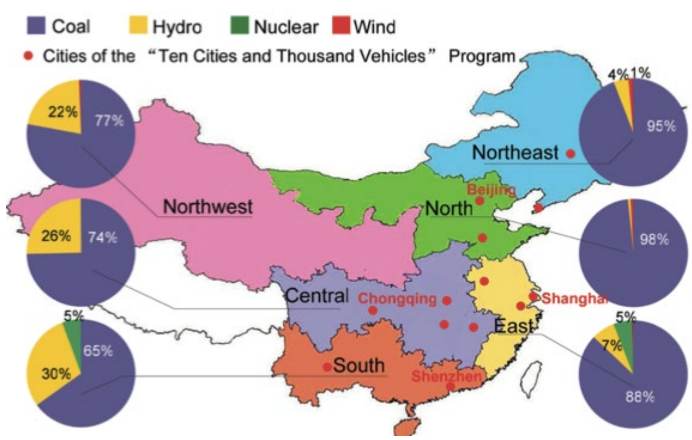
5. Electric Vehicles' Impact on the Energy Mix and Human Health

EVs require energy from electricity generation plants. Some scientific studies suggest that if China maintains its current electricity mix, the benefits of widespread EV adoption for greenhouse gas emissions will be limited at best, and possibly negative. The anticipated consequences for human health are difficult to calculate, but by no means clearly favor electric vehicles.

Emissions associated with EVs depend on the mix of sources that feed into the grid. At present, coal accounts for around 80% of electricity production in China, compared with 39% in the United States.[102] China is expected to see slower but continued growth in overall coal-based electricity generation. The U.S. EIA projects that China's coal use will increase from 69.4 quadrillion Btu in 2010 to 99.6 quadrillion Btu in 2020, which translates into emissions rising from 6,520 million metric tons of CO_2 (mmt) to 9,409 mmt. The comparable forecasts for the U.S. are 18.6 quadrillion Btu of coal use in 2020, emitting 1,769 mmt CO_2.[103] In September 2013 the State Council announced it would try to reduce coal's proportion of the overall fuel mix (not just electricity generation) from 70% in 2013 to 65% in 2017.[104] Adding a new demand source in the form of EVs will make this task harder.

The energy mix is not uniform across China's regions. In the north and northeast, coal accounts for over 90% of electricity production, whereas in the southern and western regions, where hydropower is more abundant, coal-fired generation is below 80%. EVs will have lower social costs if deployed in less coal-intensive regions.

Figure 9: Regional Sources for Electricity Generation and Cities in the "Ten Cities Thousand Vehicles" Program[105]



102 The U.S. figure is based on the 12 months from July 2012-July 2013. Sources: EIA. 2013. "Electric Power Monthly." July. http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_1; Reuters. 2013. "China power output rises for fourth month on economy, weather." September 10. http://in.reuters.com/article/2013/09/10/china-output-power-idINL3N0H616620130910

103 EIA. 2013. "International Energy Outlook 2013." July. http://www.eia.gov/forecasts/ieo/ieo_tables.cfm

104 Spegele, Brian. 2013. "China pledges to cut coal consumption." *The Wall Street Journal.* September 11.

105 Hong Huo et al . 2010. "Environmental Implication of Electric Vehicles in China." *Environment, Science, and Technology.* Volume 44.

Further, all power plants are not made equal; recently constructed coal plants are either supercritical, ultra-supercritical, or integrated-gasification combined cycle (IGCC), which have energy efficiency ratings of between 41% and 47%. The extent to which China can replace old, sub-critical power plants (with about 33% efficiency) with much more efficient new plants, the emission cost of EVs will be lower.

A 2012 study by scholars at the Norwegian University of Science and Technology examines vehicle production, usage, end of life, and supply chains.[106] They find that EVs are unambiguously counterproductive when electricity is primarily coal-fired. Under such conditions, at best local pollution reduction is possible as EVs move pollution away from some local areas rather than removing emissions broadly. They conclude that "Only limited benefits are achieved by EVs using electricity from natural gas…a greater reduction in global warming potential could potentially be achieved by increasing fuel efficiency or shifting from gasoline to diesel ICEVs without significant problem-shifting (with the exception of smog)." The problem-shifting the study refers to is that the EV supply chain has a much higher potential for human toxicity than conventional vehicles as a result of the disposal of byproducts in mining copper and nickel.

China houses seven of the world's ten most air-polluted cities.[107] In 2010, outdoor air pollution was responsible for 1.2 million premature deaths in China, according to an epidemiological study.[108] The map below shows real-time particulate (PM 2.5) and ozone pollution readings from stations around China, ranging from Good (green) to Unhealthy (red) to Very Unhealthy (purple) to Hazardous (maroon). The data comes from China's Ministry of Environmental Protection, which uses the US EPA standards for ratings and associated warnings ("Hazardous" means "Health alert: everyone may experience more serious health effects"). A similar map for Los Angeles on the same day (LA is one of the most consistently polluted region in the U.S.) has only green and yellow.[109]

[106] Hawkins et al. 2012. "Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles." *Journal of Industrial Ecology*. Vol 17, Issue 1.

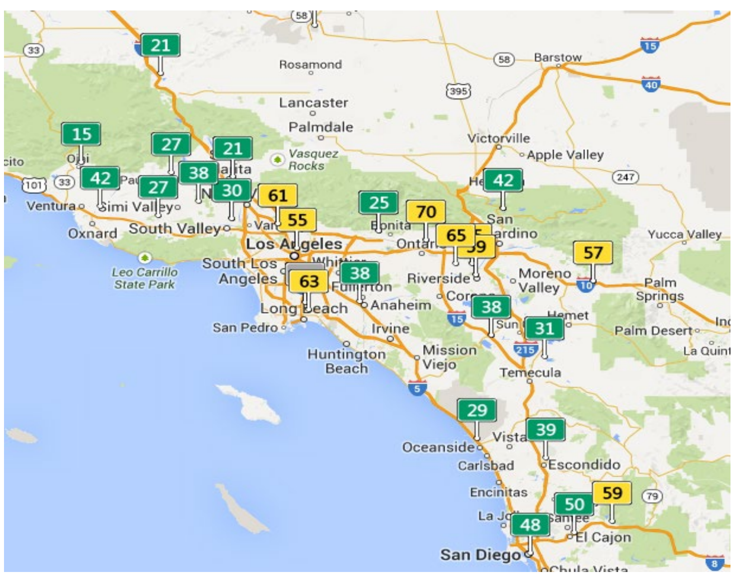
[107] Staedter, Tracy. 2013. "7 of 10 Most Air-Polluted Cities are in China." *Discovery News.* January 16. http://news.discovery.com/earth/weather-extreme-events/7-of-10-most-air-polluted-cities-china-130116.htm. Kelland, Kate and Stephanie Nebehay. 2013. "The air we breathe is laced with cancer causing substances." *Reuters.* October 17. http://www.reuters.com/article/2013/10/17/us-cancer-pollution-idUSBRE99G0BB20131017

[108] Wong, Edward. 2012. "Air pollution linked to 1.2 million premature deaths in China." *The New York Times.* April 1.

[109] Airnow. 2013. U.S. Government. www.airnow.gov.

Figure 10: Ozone and PM2.5 Readings in China, October 18, 2013[110]

Figure 11: Ozone and PM2.5 Readings in Los Angeles, October 18, 2013[111]



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110 AQICN. 2013. Available at http://aqicn.org/map/china/. Accessed October 18.

111 AQICN. 2013. Available at http://aqicn.org/map/usa/. Accessed October 18.

Existing studies suggest that given existing conditions, EVs would not lead to substantial health benefits. The 2012 study by researchers from the U.S. and Tsinghua cited above also compares emissions of CO_2, PM2.5, NOx, and hydrocarbons, as well as the environmental health impacts associated with PM2.5 from the use of conventional vehicles and EVs in 34 large Chinese cities.[112] They focus on population exposure rather than simply the emissions, and find that the impacts of EVs on health are ambiguous. In most of the cities, they find that even after accounting for the shifting of pollution from roads to power plants, replacing ICE vehicles with EVs still increases mortality risk from PM2.5. The authors conclude that "Chinese policy makers should proceed carefully with deployment of plug-in and BEV vehicles and consider aggressive improvements in the power sector to realize anticipated gains in emissions and health."

VII. Concluding Thoughts

China's failure to deploy EVs contrasts with certain other successfully implemented policies. Notable examples are China's phase-out of leaded gasoline and the imposition of European emissions standards in the 2000s. While it took the U.S. 26 years to eliminate lead in gasoline (1970-96), China did it between 2000 and 2009. Similarly, emissions standards following the EU regime were implemented nationwide between 1999 and 2013. Euro 1 took effect in 1999, and then certain cities took the lead for each subsequent standard, with Beijing first adopting the most rigorous standard, Euro IV, in 2012, and the rest of the country doing so in 2013. Widely cited as reasons for these successes is the strong support of local governments in the face of significant public pressure around pollution.

Why has China consistently failed to meet its EV targets? The main reason is the same for China as it is for the United States and Europe. EV technologies are substantially more expensive than conventional ICE vehicles. The culprit is high battery costs, which add upward of $14,000 to the initial cost of a compact EV or PHEV. Subsidies can overcome a portion of this barrier, but such subsidies are limited both temporally and spatially. In the end, full size EVs are unlikely to penetrate the market beyond fleet vehicles in some cities until either battery costs are substantially reduced or gasoline and diesel prices increase dramatically.

On the other hand, change in China happens very rapidly, and the government does not appear to be abandoning its lofty EV ambitions.[113] Expanding charging infrastructure is essential. Thus far investment has been insufficient, particularly for private vehicles. Neither the state grid companies nor the state-owned automakers appear interested in investing ahead of consumer demand. This demand depends on vehicle cost and consumer comfort with the safety and limited driving range of EVs.

In addition to the unexpectedly difficult infrastructure challenge, it seems the Chinese government was over-optimistic about the technological capacity of China's domestic automakers. It overestimated the amount of technology transfer that foreign firms had imparted on their domestic JV

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[112] Shuguang Ji et al. 2012. "Electric Vehicles in China: Emissions and Health Impacts." *Environmental Science and Technology.* Vol 46.

[113] Gordon Orr, a partner at Mckinsey's Shanghai office, recently wrote in early 2014 that "The coming months are also likely to see another effort to create a real Chinese electric-vehicle market." Orr, Gordon. 2014. "What could happen in China in 2014?" McKinsey & Co, Insights

partners. An absence of data in the Chinese policymaking process helps explain why basic drivers in the Chinese vehicle market, as well as more tangible issues such as battery costs, were poorly understood.

The partial liberalization of the auto market has inadvertently made EV deployment even more difficult. In the 2000s, liberalization following WTO accession allowed a group of new, private automakers to enter and produce cheap, domestically branded cars. At the same time, more foreign firms were able to establish JVs to build their cars in China. However, alternative fuel vehicle trade barriers actually grew. The government mandated such extraordinary technology transfer from foreign firms wishing to produce or sell electric vehicles in China that no foreign firms with BEV capability have thus far entered the market (with the possible exception of Tesla). With no capable domestic firms and no foreign entry, it is no surprise that China has systematically missed its targets for EV deployment.

China has primarily used temporary subsidies in select pilot cities to promote EV deployment. The government seems uncomfortable with the current approach. EV proponent and Minister of Science and Technology Wan Gang said in 2013 that government subsidies are "short-term solutions," and a sustainable industry will require raising technology levels and lowering costs.[114] How to do this is the conundrum, and China is at a particular disadvantage compared with other countries with significant EV programs – Germany, Japan and the U.S. – because its domestic auto companies have low levels of technology and quality capability, and the government has maintained high trade barriers to foreign technology. Paradoxically, uncertainty about future subsidies has discourage automakers from pursuing EVs full throttle. Instead, it may be optimal for them to remain in a holding pattern until the policy's permanence is established.[115]

The central government directs much of its R&D funding to large state-owned firms via loans and grants. This strategy is in opposition to studies suggesting that entrepreneurs and the small, young firms they establish are critical to creating innovation ecosystems.[116] In China, small private firms are actually at a disadvantage, with little access to capital markets and fewer connections with key government officials.

Local air pollution is an urgent crisis facing China's leaders. The government appears to believe that broad EV deployment will cut urban air pollution and associated damage to human health.[117] EVs have zero tail-pipe emissions, a clear advantage over the smog-generating emissions from ICE vehicles. But if the increased electricity demand is met with coal, these gains may be offset depending on power plant efficiency, proximity to densely populated areas, and use of environmental controls like scrubbers. Burning coal emits a cocktail of pollutants including sulfur dioxide,

114 He Wei. 2013. "R&D Support needed for EV industry." *China Daily Asia.* May 31. http://www.chinadailyasia.com/business/2013-05/31/content_15075198.html

115 Wang Haiyun (王海蕴). 2013. "Testing the new energy vehicle industry (x*in nengyuan qiche de chanye hua kaoyan*新能源汽车的产业化考验.)" State Council Development Research Center Financial Services Sector (*guowuyuan fazhan yanjiu zhongxin caijin jie*国务院发展研究中心 财经界). August 8.

116 Evans, D. S. (1987). The relationship between firm growth, size, and age: Estimates for 100 manufacturing industries. The journal of industrial economics, 567-581.

117 E.g. State Council (*zhongguo renmin gongheguo guowuyuan* 中华人民共和国国务院). 2012. "Energy Saving and New Energy Auto Industry Development Plan (2012-2020) (*jieneng yu xin nengyuan qiche chanye yu fazhan guihua*节能与新能源汽车产业发展规划（2012—2020年)". June 28. http://www.gov.cn/zwgk/2012-07/09/content_2179032.htm

nitrogen oxide, particulate matter and mercury. Without substantial changes in China's mix of power generating capacity, EVs are more likely to decrease air quality while increasing health impacts.

In China, as in most countries, energy governance is profoundly political in every sense of the word, with social norms and state-society relationships as important as technological development and economic growth. Far from the finger-snapping efficiency that some Western commentators assigned to China's energy governance in the early 2000s, energy and environmental policy in China has been mired in delay, uncertainty and inconsistent enforcement. Central regulations and targets have sought to reduce pollution for decades. The local officials and state-owned company executives responsible for carrying out these policies have frequently either had their own divergent agendas or respond to economic growth incentives that are contradictory to environmental protection and energy conservation. The same problems of fragmented governance policy uncertainty and conflicting incentives have plagued efforts to meet government EV targets.

The EV sector in China is evolving. But if it is to meet the ambitious goals set by its government, it must seriously explore alternative paths placing greater emphasis on a) domestic consumers, b) greater international cooperation, and c) greater collaboration between regions and companies.

Appendix A: Electric Vehicle Policy Timeline

Year	Title	What done	Subsidy type and level
1986	7th Five Year Plan	Designates autos a "pillar industry"	
Early 1990s	EV R&D support from govt begins		
1994	State Council	Formal Policy on Development of Automotive Industry	
1998	National Automotive Standardization Technical Committee established for Evs	EVSC subsequently sets range of EV standards	
	Standardization Committee(EVSC)		
1999	National Clean Vehicle Action	12 cities hten 20 cities in successful CNG and LPG demonstration program, mostly retrofitting	MOST invested Y50 mill RMB, local gov'ts invested billions more
2001	National 863 R&D Program begins	Firms like li-ion maker BAK battery get grants	Total of Y2 billion spent on Evs
2004	New Automotive Industry Policy	Consolidation; brand building; design	Discriminated against imported parts
2006	National Guidelines on Medium- and Long-term Program for Science and Technology Development (2006-2020)	Emphasized effeicient and alternative fuel vehicles	
2006	11th Five Year Plan	Targets specific vehicle components for support, focus on energy efficient/alternative energy vehicles	Y4.7 billion for R&D for energy eff. vehicles
2007	State Grid public EVs trial plan	State Grid to convert public transit, taxis, sanitation trucks to EVs on trial basis in certain cities, and develop a nationawide network of charging stations	
2007	Rules on the Production Admission Administration of New Energy Automobiles	NDRC release	
2008	MOST announced "Ten Cities Thousand Vehicles" project	Aim for 100 HEVs, BEVs, FCVs in municipal fleets of each of 13 cities, build required charging stations in 3 yrs.	$15 billion of gov't money committed at this time to overall EV agenda at this time
2009	MIIT IP Regulations	Domestic enterprise must own IP for motor, battery and inverter for EVs made in China	
2009	Notice on New Energy Vehicle Demonstration and Extension Work	Subsidize public sector purchase of EVs in 13 cities for use as taxis, sanitation, postal service, police.	60,000 yuan subsidy for BEV, 50,000 yuan for advanced hybrids (only for public sector use)
2010	New energy vehicle development program	NDRC launces new NEV support program	
2010	Ten Cities, Thousand Vehicles Program	Program has expanded to 25 cities, 5 identified for private subsidy as well as public fleet subsidy. Only private buyers in these cities get subsidy	Pilot city subsidy programs include free electricity for 3 yrs for private buyers, exemption from license registration in Beijing and Shanghai
2011	NEV IP & Ownership Requirement	NEV parts manufacturers must be >50% domestic-firm owned	
2011	Target	NEV target of 500,000 is missed	
2012	EV Sales Tax Waiver+Subsdies	Imported EVs now face a 25% customs duty, sales tax, and no subsidy.	EVs made in China get 9% sales tax waived, plus subsidies up to 120,000 yuan in certain cities
2012	State Council Strategic Industry Policy	NEVs identified as one of 7 strategic industries.	
2012	Target	All but a few cities in Ten Cities Thousand Vehicles program miss target	
2012	State Council Energy Saving and New Energy Vehicle Industry evelopment Plan	Goal of 500,00 BEVs and PHEVs, deployed, as well as 2000 charging/swapping stations, by 2015, and 5 million vehicles by 2020.	MOST, MOF, MIIT agree to invest over 100 billion RMB ($15 billion) to achieve target
2013	Subsidy renewal	NDRC announces all-electric vehicle subsidy to be renewed. Hybrids excluded	As much as Y60,000 subsidy for EV, Y500,000 for FCV, and Y500,000 for EV bus. Hybrids retain Y3000 subsidy under different vehicle eff. provision

Appendix B: Note on Natural Gas Vehicles

NGVs in China have been widely deployed in public taxi and bus fleets, and in interior, poorer cities there has been extensive demand for conventional vehicle retrofits. NGVs are desirable for their lower operating cost - converting a vehicle from gasoline to natural gas reduces fuel costs by about half or more in many areas. They make sense in areas with access to cheap natural gas, primarily Xinjiang and Sichuan in the country's West.

Mostly driven by local government fleet purchases (as with EVs), the NGV stock in China has increased dramatically over the last five years. A Citigroup report found that China had about 1.5 million NGVs on the roads in 2012, compared to 0.1 million in 2005.[118] The U.S. only has about 135,000 NGVs. There are natural gas refueling facilities in at least 80 cities, and well over 1,000 individual stations.

The main options for fueling light duty vehicles with natural gas are liquid petroleum gas (LPG) and compressed natural gas (CNG). Most conversions in China have been to CNG. These converted vehicles are not terribly fun to drive, and are seen in the big coastal cities as a "poor man's" car.

While they produce somewhat lower CO_2 emissions than conventional vehicles, these converted engines also tend to foul up catalytic converters much more quickly and have led to intense pollution, particularly smog caused by nitrogen emissions. This problem is especially intense in Hong Kong, where most taxis and light commercial vehicles use LPG or CNG. Hong Kong is now undergoing a very costly replacement program for tens of thousands of catalytic converters, which in the future will have to be replaced every 18 months. Indeed, observing many cities in China trying to replicate their switch to natural gas, Hong Kong officials have actually warned their counterparts in Beijing about the potential pollution problem from simple conversions of conventional vehicles to natural gas powered vehicles.[119]

Long distance, heavy-duty trucks may present a more viable application for natural gas, in a third formulation: liquefied natural gas (LNG). China already has more than 40,000 LNG-fueled trucks.[120] In 2012, LNG truck sales totaled 3,020, according to a different source.[121] A Sanford Bernstein analysis in 2013 found that even with increased natural gas prices, the payback period from conversion to LNG was only 16 months, with monthly fuel savings of ¥7,282.

It may be, therefore, that a strategy targeting different alternative fuels for different applications and in different parts of the country makes the most sense. Heavy trucks can run on LNG, light duty vehicles in gas-rich areas might run on CNG, and the megalopolises in China's east could focus on EVs. Meanwhile, low-speed EVs could be deployed in rural areas.

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Appendix C: All Light Duty Electric and Fuel Cell Vehicles Approved for Sale in China by MIIT, through January 2014

FB: Foreign Brand
APP: Available for Private Purchase

MIIT cert. date	Automaker	品牌	Brand	FB	Description	Power-train	Model	Range (km)	APP	Price (Yuan)	Given / sold to city gov't?
Jun-05	FAW-Toyota	丰田牌	**Toyota**	Y	The Prius was the first electric drive car produced in China, at the Sichuan FAW-Toyota facility	**HEV**	**Prius**		Y	295,000	
Aug-09	BYD	比亚迪牌	**BYD**	N	PHEV F3DM. Originally began selling to gov't/ corporate customers in 2008, sold 48 vehicles, started selling to general public in 2010, at 169,800 yuan, compared to 59,800 yuan for basic F3	**PHEV**	**F3DM**	100 km EV, then gasoline	Y	169,800	
Sep-09	Changan	长安牌	**Changan**	N	Hybrid compact MPV, the Jiexun first debuted in 2007	**HEV**	**Jiexun**		Y	144,000	Used in 2008 Beijing Olympic NEV demonstration
Sep-09	Chery	奇瑞牌	**Chery**	N	Hybrid sedan. Planned to launch but never sold.	**HEV**	**A3 ISG**		N		
Sep-09	Chery	奇瑞牌	**Chery**	N	Hybrid version of popular Chery family sedan	**HEV**	**A5 BSG**		N		
Sep-09	Chery	瑞麒牌	**Chery Riich**	N	2009 model of M1 EV, compact city car also called S18 EV	**BEV**	**2009 S18/M1 EV**	135	Y	149,600	
Sep-09	Dongfeng Zhengzhou Nissan	东风牌	**Dongfeng**	N	SUV, not clear if more than 1 was produced	**BEV**	**Odin**		N		
Nov-09	Changan Hafei	哈飞牌	**Hafei**	N	The first Hafei Saibao sedan was exported to the US to be sold as the Coda EV	**BEV**	**2009 Saibao**	180-210	N		
Nov-09	Dongfeng Zhengzhou Nissan	东风牌	**Dongfeng Ruiqi**	N	SUV, not clear if more than 1 was produced	**BEV**	**Ruiqi**		N		
Jan-10	BYD	比亚迪牌	**BYD**	N	First e6, not for sale. Copy of Honda Odyssey	**BEV**	**2010 e6**		N		Tested 40 in Shengzhen as taxis
Jan-10	BYD	比亚迪牌	**BYD**	N	M6 electric MPV	**BEV**	**M6**		N		

MIIT cert. date	Automaker	品牌	Brand	FB	Description	Power-train	Model	Range (km)	APP	Price (Yuan)	Given / sold to city gov't?
Jan-10	Changan	长安牌	**Changan**	N	Hybrid	**HEV**	**C Class Hybrid**		Y		
Jan-10	Dongfeng	风神牌	**Fengshen**	N	Hybrid version of Fengshen S30 sedan	**HEV**	**S30 Hybrid**		N		Donated 100 to Wuhan gov't
Jan-10	FAW Haima	海马牌	**Haima**	N	First Freema demon-stration vehicle	**BEV**	**2010 Freema**		N		
Jan-10	SAIC GM	别克牌	**Buick**	Y	Hybrid version of Buick Lacrosse	**HEV**	**2010 La-Crosse Eco-Hybrid**		Y	277,000	
Apr-10	Changan	长安牌	**Changan**	N	Hatchback MPV 250,000 yuan	**FCV**	**Z-Shine**		N		
Apr-10	Chery	奇瑞牌	**Chery**	N	Chery FCV developed with Tsinghua	**FCV**	**Eastar FCV**		N		
Apr-10	FAW	红旗牌	**FAW Hongqi**	N	Demonstration FCV, only for Shanghai World Expo	**FCV**	**N/A**		N		
Apr-10	Jiangnan	江南牌	**Jiangnan**	N	Sedan	**BEV**	**N/A**		N		
Apr-10	Jiangnan	江南牌	**Zotye**	N	SUV, based on a Fiat Multiplia platform and copy of Daihatsu Terios	**BEV**	**5008 Nomad II EV**	200	Y	210,000	
Apr-10	Jiangnan	众泰牌	**Zotye**	N	Minivan, 250,000 yuan	**BEV**	**M300 (Langyue) EV**	200	Y	250,000	
Apr-10	SAIC	上海牌	**Roewe (Rongwei)**	N	One of 3 prototype FCVs released at the same time under the Roewe brand. They differ only in their motor and possibly battery source. One is from 上海电驱动有限公司 (Shanghai Qudong Ltd Co)	**FCV**	**750 E v1**		N		
Apr-10	SAIC	上海牌	**Roewe (Rongwei)**	N	One of 3 prototype FCVs released at the same time under the Roewe brand. They differ only in their motor and possibly battery source. One is from 上海大郡自动化系统工程有限公司 (Shanghai Dajun Zidonghua xitong Gongcheng Ltd Co)	**FCV**	**750 E v2**		N		

MIIT cert. date	Automaker	品牌	Brand	FB	Description	Power-train	Model	Range (km)	APP	Price (Yuan)	Given / sold to city gov't?
Apr-10	SAIC	上海牌	**Roewe (Rongwei)**	N	One of 3 prototype FCVs released at the same time under the Roewe brand. This one is a hybrid plug in FCV that used a Johnson Controls li-ion battery and a GM motor.	**FCV**	**750 E v3**		N		
May-10	Brilliance	中华牌	**Brilliance**	N	BS6 sedan hybrid version, due to terrible safety record the line was subsequently withdrawn	**HEV**	**BS6 Hybrid**		N		
Jun-10	Brilliance	中华牌	**Brilliance**	N	Junjie FSV sedan, just trial	**HEV**	**Junjie FSV**		N		Donated 400 vehicles to Dalian gov't
Jun-10	Changan	长安牌	**Changan**	N	BenBen Love, a compact, only for demonstration	**BEV**	**Benben Love**	150	N		
Jun-10	GAC Toyota	丰田牌	**Toyota**	Y		**HEV**	**2010 Camry Hybrid**		Y	340,000	
Jun-10	Geely	豪情牌	**Geely**	N	Under Geely's sub-brand Gleagle, this is a mini car with li-ion battery and max speed of 150 km/hr, an electric version of the Panda. It is a somewhat improved version of the earlier EK1	**BEV**	**Gleagle EK2**	180	Y	100,000	
Jun-10	Geely	豪情牌	**Geely**	N	Under Geely's sub-brand Gleagle, this is a mini car with only a lead-acid battery an max speed of 80 km/hr, an electric version of the Panda. It is a somewhat improved version of the earlier EK1	**BEV**	**Gleagle EK1**		N		
Sep-10	Chery	奇瑞牌	**Chery**	N	EV version of QQ3	**BEV**	**2010 QQ3 EV**	100	Y	40,000	
Sep-10	Chery	瑞麒牌	**Chery Riich**	N		**BEV**	**2010 S18/M1 EV**	135	Y	150,000	
Sep-10	Lifan	力帆牌	**Lifan**	N	Lifan first EV, used in demonstration	**BEV**	**2010 620 EV**		N		
Nov-10	FAW	红旗牌	**FAW Hongqi**	N	Demonstration EV, only for Shanghai World Expo	**BEV**	**N/A**		N		
Nov-10	Jianghuai	江淮牌	**Jianghuai**	N	2nd best selling EV in China after QQ3, also called Tongyue	**BEV**	**J3 Turin EV**	130	Y	158,000	

MIIT cert. date	Automaker	品牌	Brand	FB	Description	Power-train	Model	Range (km)	APP	Price (Yuan)	Given / sold to city gov't?
Nov-10	Jiangling	江铃牌	**JMC**	N	This vehicle is an EV version of an existing Landwind sedan, which is a brand of Jiangling, but this vehicle does not appear branded with the Landwind marque. Has a max speed of 85 km/h	**BEV**	**Jiangling Landwind Fenghua EV**		N		
Dec-10	Jiangling	江铃牌	**JMC**	N		**HEV**	**NA**		N/A		
Feb-11	Dongfeng Zhengzhou Nissan	东风牌	**Dongfeng Ruiqi**	N	Minicar, concept for Shanghai 2011 auto show only	**BEV**	**I-car**		N		
Apr-11	Changan	长安牌	**Changan**	N	Concept EV showsn at 2011 shanghai auto show, beijing and chongqing city gov's ordered a lot	**BEV**	**E30 (concept vehicle**	126	N		
May-11	Chery	瑞麒牌	**Chery Riich**	N		**BEV**	**2011 S18/M1 EV**	135	Y	200,000	
May-11	FAW-VW	开利牌	**Kaili**	N	Kaili (Carely) is a VW-FAW sub-brand designed to sell only NEVs	**BEV**	**Bora EV**		N		
Jul-11	BYD	比亚迪牌	**BYD**	N	Second e6, sold to public starting in late 2011, 2 years behind schedule	**BEV**	**2011 e6**		Y	369,800	Sold 300 to Shenzhen for use as taxis
Jul-11	Changan	长安牌	**Changan**	N	CX30 hybrid	**HEV**	**CX30 hybrid**		Y		
Jul-11	FAW Haima	海马牌	**Haima**	N	The Haima Prince EV, an electrified version of the Prince compact sedan, was built solely for the 2011 Shanghai auto show	**BEV**	**Prince EV**		N		2 given to the Shanghai demonstra-tion zone
Jul-11	Nanjing Auto	依维柯牌	**Naveco**	N	Nanjing-Iveco JV sub-brand, this appears to be a small bus	**BEV**			N		
Aug-11	SAIC GM	别克牌	**Buick**	Y	Hybrid version of Buick Lacrosse	**HEV**	**2011 Lacrosse Eco-Hybrid**		Y	300,000	
Aug-11	SAIC GM	赛欧牌	**Sail**	N	Demonstration only, Chevy Sail Springo EV	**BEV**	**2011 Springo EV**		N		
Sep-11	Dongfeng	东风牌	**Dongfeng**	N	Dongfeng EJo2, a mini concept car, shown at 2011 Shanghai auto show, later called the E30	**BEV**	**EJo2**	110-180	N		
Sep-11	Jiangxi Changhe Suzuki	利亚纳牌	**Suzuki**	Y	This EV version of the Liana sedan was built for the 2011 Shanghai auto show	**BEV**	**Liana EV**		N		

MIIT cert. date	Automaker	品牌	Brand	FB	Description	Power-train	Model	Range (km)	APP	Price (Yuan)	Given / sold to city gov't?
Sep-11	SAIC VW	天越牌	**Tantus (Tianyue)**	N	VW and SAIC created Tantus subbrand (50/50 JV) to build an EV. Motor from Shanghai Electric Drive Ltd., battery from Shanghai Jie New Power Battery Systems Co., Ltd.	**BEV**	**Tantus EV**		N		
Oct-11	Chery	奇瑞牌	**Chery**	N	EV version of QQ3	**BEV**	**2011 QQ3 EV**	100	Y	40,000	
Oct-11	Southeast	东南牌	**Soueast**	N	SouEast 9 passenger electric van, revoked, not for sale	**BEV**			N		
Dec-11	Beijing Hyundai	首望牌	**Shouwang**	N	Shouwang, the joint domestic sub-brand of BAIC-Hyundai JV to make cheap, green cars. Electric version of Elantra	**BEV**	**Shouwang EV (Elantra EV)**		N		Sold 50 to Beijing for taxis
Dec-11	Changan	长安牌	**Changan**	N	E30 for government use - produced 100 to be taxis	**BEV**	**E30**		N		Gave or sold large numbers to Beijing government for use in Fangshan demonstration zone
Dec-11	FAW Haima	海马牌	**Haima**	N	Electric version of Haima 3	**BEV**	**3 EV**		N		
Dec-11	FAW Haima	海马牌	**Haima**	N	Actually for sale, Haima Freema electric minivan	**BEV**	**Freema**	160	Y	160,000	
Dec-11	Jiangnan	众泰牌	**Zotye**	N	2011 version	**BEV**	**5008 Nomad II EV**		Y	210,000	
Jan-12	Great Wall	长城牌	**Great Wall**	N	Sporty 4-door cross-over vehicle	**BEV**	**Haval M3 EV**	160	Y	100,000	
Feb-12	Chery	瑞麒牌	**Chery Riich**	N		**BEV**	**2012 S18/M1 EV**	135	Y	200,000	
Feb-12	Jiangnan	江南牌	**Jiangnan**	N	An old sedan outfitted with a lead acid battery	**BEV**	**E300**		N		
Mar-12	Dongfeng	启辰牌	**Kai Chen**	N	Kai Chen is a Dongfeng Nissan sub-brand.	**BEV**	**R50 EV**		N		
Mar-12	GAC	传祺牌	**Trumpchi (Zhuanqi)**	N	Hybrid version of the Chi Chuan GS5	**HEV**	**Chi Chuan GS5 Hybrid**		Y		
Mar-12	GAC	传祺)牌	**Trumpchi (Zhuanqi)**	N	Shown at Beijing auto show, not clear if this 4WD sedan went on sale	**HEV**	**4WD Hybrid**		N/A		
Mar-12	Jiangling Ford	江铃牌	**JMC**	N	A compact hatchback	**BEV**			N		

MIIT cert. date	Automaker	品牌	Brand	FB	Description	Power-train	Model	Range (km)	APP	Price (Yuan)	Given / sold to city gov't?
Mar-12	KIA	典悦牌	**Dian Yue**	N	Dian Yue is a subrand of the Dongfeng-Yueda-Kia JV. This car is based on the old Kia Cerato.	**BEV**	**N30**		N		
Mar-12	SAIC	荣威牌	**Roewe (Rongwei)**	N	SAIC's champion EV, with batteries from now-defunct A123	**BEV**	**E50**	110-180	Y	234,900	
Apr-12	Lifan	力帆牌	**Lifan**	N	Upgraded version of the earlier Lifan EV sedan, for sale 249,000 yuan actually for sale	**BEV**	**2012 620 EV**	160	Y	100,000	
Jun-12	GAC Toyota	丰田牌	**Toyota**	Y		**HEV**	**2012 Camry Hybrid**		Y	320,000	
Jun-12	Sichuan Yema	野马牌	**Yema**	N	This station wagon is based on Yema's F16, which is in turn very closely based on the Audi A4 Avant. Battery from China Aviation Lithium Battery Co., Ltd.,	**BEV**	**F16 EV**		N		For taxis in Chengdu, Sichuan
Aug-12	GAC Toyota	丰田牌	**Toyota**	Y	High end sporty concept car shown at 2012 Beijing Motor Show, tech developed at Toyota's R&D facility in Changshu.	**HEV**	**Yundong Shuangqing**		N		
Sep-12	Changan Hafei	哈飞牌	**Hafei**	N	New Saibao EV debuted at Beijing auto show in 2012, its electric powertrain is same as Chang'an E30	**BEV**	**2012 Saibao**	200	Y	180,000	
Oct-12	Dongfeng	风神牌	**Fengshen**	N	Electric version of Fengshen S30 sedan	**BEV**	**S30 EV**	150	N		
Oct-12	SAIC GM	赛欧牌	**Sail**	N	Sail Springo EV, priced at $40,000	**BEV**	**2012 Springo EV**	130	Y	260,000	
Nov-12	Brilliance	中华牌	**Brilliance**	N	EV version of H230	**BEV**	**H230 EV**		N		
Nov-12	Tianjin FAW Xiali	威志牌	**Weizhi**	N	Tianjin Weizhi brand demonstration EV, not for sale	**BEV**			N		
Dec-12	BYD Automobile Co., Ltd.	比亚迪牌	**BYD**	N	Copy of Honda Odyssey	**BEV**	**2012 e6**	300	Y	300,000	Sold 500 to Shenzhen for use as police cars
Dec-12	FAW	一汽牌	**Besturn**	N	Besturn B50 EV, Only produced 20 alternative energy vehicles (the Evs plus PHEVs)	**BEV**	**B50 EV**	111	N		

MIIT cert. date	Automaker	品牌	Brand	FB	Description	Power-train	Model	Range (km)	APP	Price (Yuan)	Given / sold to city gov't?
Dec-12	FAW	一汽牌	**Besturn**	N	Besturn B70 PHEV, independently developed by FAW. Only produced 20 alternative energy vehicles (the Evs plus PHEVs)	**PHEV**	**B70 PHEV**	44	N		
Dec-12	Jianghuai	江淮牌	**Jianghuai**	N	Mini car, Hybrid version of J2 sedan, used to be A0 and branded as Yueyue supermini	**HEV**			N		
Jan-13	GAC	传祺牌	**Trumpchi (Zhuanqi)**	N	Hybrid version of Trumpchi GA3 compact sedan	**HEV**	**GA3**		N		
Jan-13	GAC	传祺牌	**Trumpchi (Zhuanqi)**	N	Hybrid version of Trumpchi GA5 sedan	**HEV**	**GA5**		N		
Feb-13	KIA	华骐牌	**Huaqi**	N	Huaqi (Horki) brand (Kia's for Chinese market), electric car called Huaqi based on Kia Cerato	**BEV**	**Huaqi EV**		N		produced to give away to local governments and for demonstration
Feb-13	Southeast	东南牌	**Soueast**	N	Electric version of Soueast V3, EV chassis entirely developed indigenously	**BEV**	**V3 electric**		N		
May-13	Dongfeng	风神牌	**Fengshen**	N	Electric version of Fengshen (Aeolus) E30, minicar, to start sales in 2014	**BEV**	**E30**		N		
May-13	Jiangnan	众泰牌	**Zotye**	N	2013 version	**BEV**	**M300 (Langyue) EV**		Y	250,000	
May-13	Kandi Technologies	康迪牌	**Kandi**	N	Kandi-Geely JV debut vehicle, not yet on market	**BEV**	**Kandi (?)**		N		
Jun-13	BAIC	北京牌	**BAIC**	N	Copy of Mercedes Benz B-class	**BEV**	**E150**	160	Y	200,000	Gave 16 to Beijing EV rental station near Tsinghua, offering additional subsidies
Jun-13	BAIC	北京牌	**BAIC**	N	Electric version of Senova-D, luxury sedan based on Saab technology	**BEV**	**Senova-D EV**		N		
Jun-13	Changan	长安牌	**Changan**	N	Electric version of Chang'an Yidong sedan, priced at 140,000 yuan	**HEV**	**Yidong**				
Jun-13	Jiangxi Changhe Suzuki	北斗星牌	**Suzuki**	Y	Electric version of van, the Suzuki Big Dipper X5	**BEV**	**Big Dipper X5**		N		

MIIT cert. date	Automaker	品牌	Brand	FB	Description	Power-train	Model	Range (km)	APP	Price (Yuan)	Given / sold to city gov't?
Jun-13	SAIC GM	别克牌	**Buick**	Y	Hybrid version of Buick Lacrosse	**HEV**	**2013 Lacrosse Eco-Hybrid**		Y	249,900	
Jul-13	Jiangnan	众泰牌	**Zotye**	N	Zotye electric minibus	**BEV**			N/A		
Jul-13	Dongfeng-Nissan	东风	**Kai Chen**	N	Nissan Leaf technology in new brand	**BEV**	**E30**		Y	300,000	
Aug-13	Chery	奇瑞	**Riich**	N	Minicar	**BEV**	**QQ EV**	100	Y		
Oct-13	FAW	一汽	**Hongqi**	N	Luxury sedan	**HEV**	**Hybrid H7**		N		
Nov-13	FAW-VW	一汽大众	**Kaili (Careley)**	N	EV version of VW Bora	**BEV**	**Carely/Kaili**	110-160	N		
Nov-13	BMW Brilliance	之诺	**Zinoro**	N	EV version of BMW X1	**BEV**	**Zinoro 1E**	150	N		
Nov-13	Geely Shanghai Maple-Kandi	上海华普-康迪	**Kandi**	N	Minicar	**BEV**	**KD-5010**	150	Y		
Nov-13	Zhengzhou Dongfeng Nissan	郑州日产汽车	**Ruiqi (Rich)**	N	EV version of the Dongfeng Rich SUV	**BEV**	**Ruiqi SUV EV**		N		
Nov-13	BYD	比亚迪	**BYD**	N		**PHEV**	**Qin**		Y		
Dec-13	Zotye	众泰	**Zotye**	N		**BEV**	**M300 EV**	160	Y		
Dec-13	BAIC	北京	**BAIC**	N	Full size car	**BEV**	**E150**	140	Y	149,800	
Dec-13	FAW-Toyota	一汽丰田	**Shi Lang (Ranz)**	N	EV version of Toyota Corolla	**BEV**	**Shilang EV**	120-150	N		Only used in Tianjin as taxi
Dec-13	Changan	重庆长安	**Changan**	N	Compact full size car, possibly version of Ford Focus	**BEV**	**Jiayue or E30**				
Jan-14	FAW	一汽	**Weizhi (Vita)**	N	Full size car	**BEV**	**Weizhi EV**		N		

Appendix D

Expense	Conventional (BYD F3)	PHEV (BYD Qin)	BEV (BYD E6)
List price in Yuan*	59,800	189,800	250,000
Base Battery cost		**$8,205**	**$14,815**
New Battery cost		$8,205	$14,815
Battery cost reduction		$0	$0
Total Purchase Costs	$9,568	$30,368	$40,000
Fuel	$9,691	$925	
Electricity		$1,114	$1,311
Maintenance	$6,145	$7,373	$3,072
Total Operating Costs	$15,835	$9,413	$4,383
Net Ownership Benefits		$0	$0
Battery Recycle Credit		$0	$0
Total Net Present Cost	**$25,403**	**$39,781**	**$44,383**
Cost Differential with Conventional Car		$14,377	$18,980

Assumptions:	
Fuel Price per Gallon:	$4.60
Battery Pack Cost ($/kWh), PHEV:	$600
Discount Rate:	10%
V2G Benefit ($ per kWh usable capacity per year):	$0
Battery Recycle Credit (% of Initial Battery Cost):	0%
Avg. Conventional MPG:	35
Miles Driven Per Year:	12,000
Useful Life Years:	10
Price of Electricity ($/kWh):	$0.08
Miles per kWh (of nominal battery capacity):	4.5
Battery Pack Cost ($/kWh), EV:	$600
Useable battery capacity, EV:	90%
Desired PHEV all-electric range (Miles):	40
Useable battery capacity, PHEV:	65%
Desired EV Range (Miles):	100
Conventional Maintenance Costs per Year:	$1,000
PHEV Maintenance Costs per Year:	$1,200
EV Maintenance Costs per Year:	$500
Avg. PHEV MPG using only fuel:	55
Percent of PHEV miles driven in electric-only mode:	85%

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