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## **ELECTRIC VEHICLES IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT IN CHINA**

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## CONTENTS

<b>I.</b>	<b>Introduction</b>	1
<b>II.</b>	<b>China’s electric automotive technology development</b>	2
	A. Battery technology development	2
	B. Electric vehicle development	5
<b>III.</b>	<b>China’s policy support for electrification of transport</b>	8
	A. The Ministry of Science and Technology and the “863 Programme”	8
	B. Bilateral cooperation in electric vehicle development	10
<b>IV.</b>	<b>Life-cycle raw material assessment, energy use and GHG emissions for electric vehicles</b>	11
	A. Impact of EV development on raw materials	11
	B. GHG emission analysis	12
	C. Case Study: On-road electric vehicles in China - GHG emission reduction potential	14
	D. Primary energy fuel extraction and transport	17
	E. Transmission and distribution losses, charging efficiency and battery efficiency	18
<b>V.</b>	<b>Conclusions and recommendations: Enhancing the sustainability of electric electric vehicles</b>	22
	A. Regionalize the development and promotion of EV in China	23
	B. Optimize grid and renewable energies for transportation uses	23
	C. Promote low-carbon version of electrification technologies, especially plug-in hybrid electric technologies	24
	D. Expand fuel economy standards to include electric vehicles	24
	<b>Annex 1</b>	26
	Case Study: Beijing City – EV in a traffic-constrained megacity	26
	<b>Annex 2</b>	27
	Case Study: Shenzhen City – policy and industrial trailblazer for EV in China	27

# Electric Vehicles in the Context of Sustainable Development in China

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## I. INTRODUCTION

1. China is facing growing challenges due to the expansion of energy demand. The country depends on imports for over 55 per cent of total oil consumption.<sup>1</sup> Since 2009, China's coal imports are greater than coal exports. As a result, the Chinese government is faced with the need to develop alternative energy systems. China also seeks to reduce greenhouse gas (GHG) emissions in every sector of the economy.

2. Transportation has been a particularly challenging sector. As China urbanizes, personal mobility becomes a central issue in the minds of city planners. People desire to live and work in different neighborhoods and at the same time increase the diversity in their social lives. Personal vehicles reflect important cultural values of success and status, making them extremely appealing from a consumer perspective. At the same time, the automotive industry employs millions of people, making it an essential target for government support.

3. Vehicles use vast amounts of energy. In China, over 98 per cent of on-road vehicles are powered by fossil fuels such as oil and gas. While alternative fuels such as ethanol, methanol, and natural gas products are being produced and researched, getting these fuels into use is difficult. Each requires its own unique distribution and handling system and often requires expensive modifications to vehicles. In addition, there is little central policy support for these technologies at this time, leading to an uncertain future for these alternative fuels.

4. China has seen an opportunity in the development of electric vehicles (EV) to make technological advances that will bring China's automotive industry into the 21<sup>st</sup> century, and at the same time make more efficient use of energy in the transport sector. Electric vehicles avoid the use of petroleum, a resource that China views as potentially limiting to its future development. China is more confident in the supply and access of increasingly efficient coal-fired electricity, and electricity from renewable energies, which, according to plan, promises to continuously decrease the carbon emissions associated with the production of electricity in China.

***Disclaimer:** The views expressed in the background paper are those of the authors and do not necessarily reflect those of the United Nations. Background papers are issued without formal editing.*

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<sup>1</sup> Available from [http://www.gov.cn/english/2010-12/21/content\\_1770592.htm](http://www.gov.cn/english/2010-12/21/content_1770592.htm)

5. Although electric vehicles have the potential to resolve many sustainability issues related to the transport sector, there are also many uncertainties from the perspectives of technology development, economic viability, consumer satisfaction and environmental sustainability.

6. This report provides a comprehensive and systematic analytical overview of China's automotive electric-drive technology development and electric mobility promotion policies and programmes. The paper analyses recent trends and projections in technology development and electricity use in private and public motor vehicles. It reviews relevant information to assess comparative efficiency of energy use and emissions by different modes of public and private transportation, analyses accessible company, product and case study information, and formulates possible policy recommendations for the further enhancement of sustainability in the electric vehicle industry in China, taking into account economic, social and environmental considerations.

## II. CHINA'S ELECTRIC AUTOMOTIVE TECHNOLOGY DEVELOPMENT

7. China is assertively committed to developing electric vehicles as a key form of transportation for the future. The Government has created a detailed roadmap for the development of EV technology, providing an enabling policy environment to foster development. The Government offers subsidies to consumers who purchase electric vehicles.

8. Figure 1 describes technology development in China as a “three-by-three” effort. The vertical columns distinguish the platforms of hybrid electric vehicles, battery electric vehicles, and fuel cell electric vehicles. The horizontal rows outline the key technologies that need to be developed to support all these modes: energy storage systems, drive train systems, and vehicles.

### A. Battery technology development

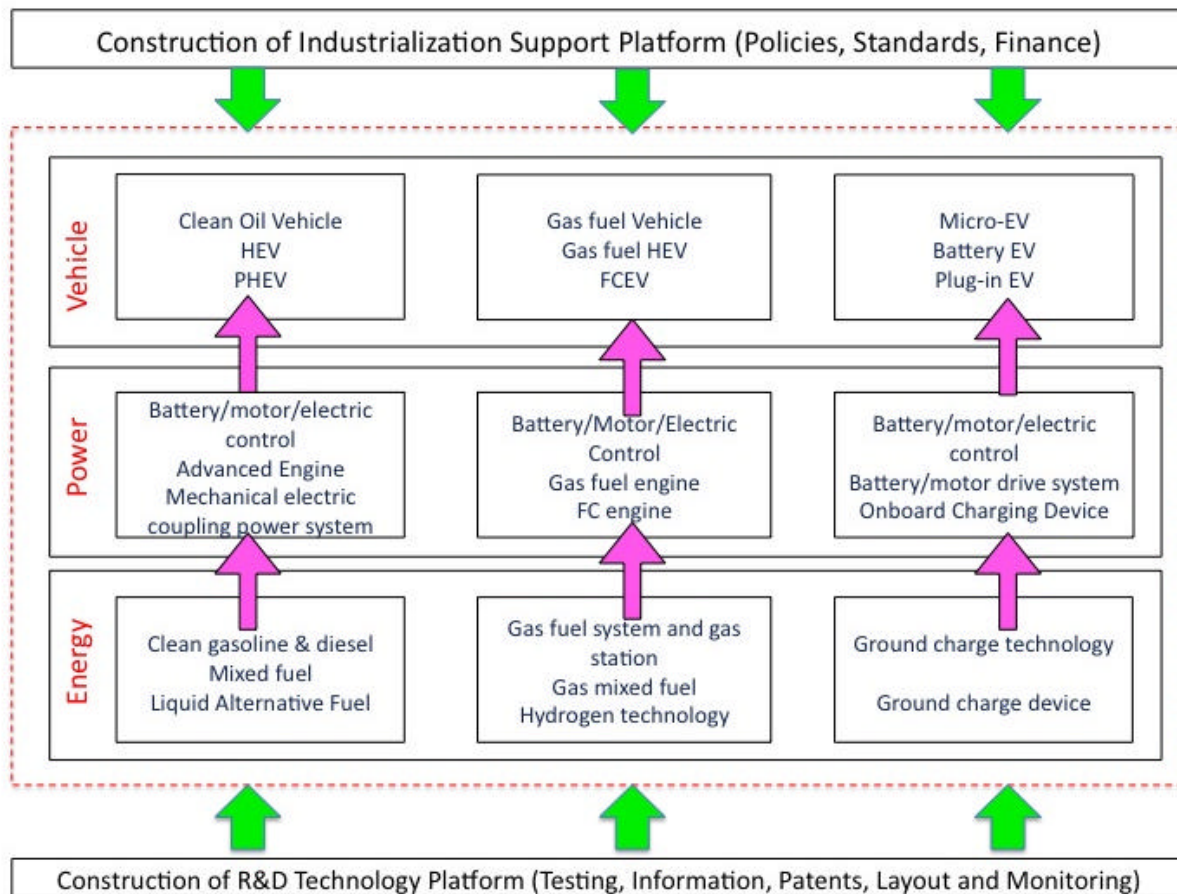
9. China is one of the world's major battery producers. BYD, BAK and Lishen battery companies, amongst others, produce most of the lithium-ion batteries for consumer electronics, particularly for mobile phones and computers. Today, a great deal of research is underway regarding battery development for the auto sector. Figure 2 illustrates some of the partnerships that have been developed for undertaking R&D in battery technology in China.

10. In spite of the large number of institutions undertaking R&D on lithium-ion batteries, Chinese companies are still lagging behind on patent registration. Japan owns 52 per cent, US owns 22 per cent and Republic of Korea owns 15 per cent of international patents for lithium ion batteries. By contrast, China holds just 1 per cent of the total patent registrations for lithium ion batteries.<sup>2</sup> A number of Chinese and other international battery makers have been sued by the University of Texas inventor of the lithium iron phosphate cathode technology. China may need to develop its own technologies in this area or face high licensing fees on lithium-ion battery production.

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<sup>2</sup> Lowe, M. et al. (2010). *Lithium-ion Batteries for Electric Vehicles: The US Value Chain*. Duke University Center on Globalization, Governance and Competitiveness.

Figure 1  
**Ministry of Science and Technology “863 Programme” technology roadmap for the 11<sup>th</sup> Five- Year Plan period**



**Source:** 2009 US-China EV Forum.

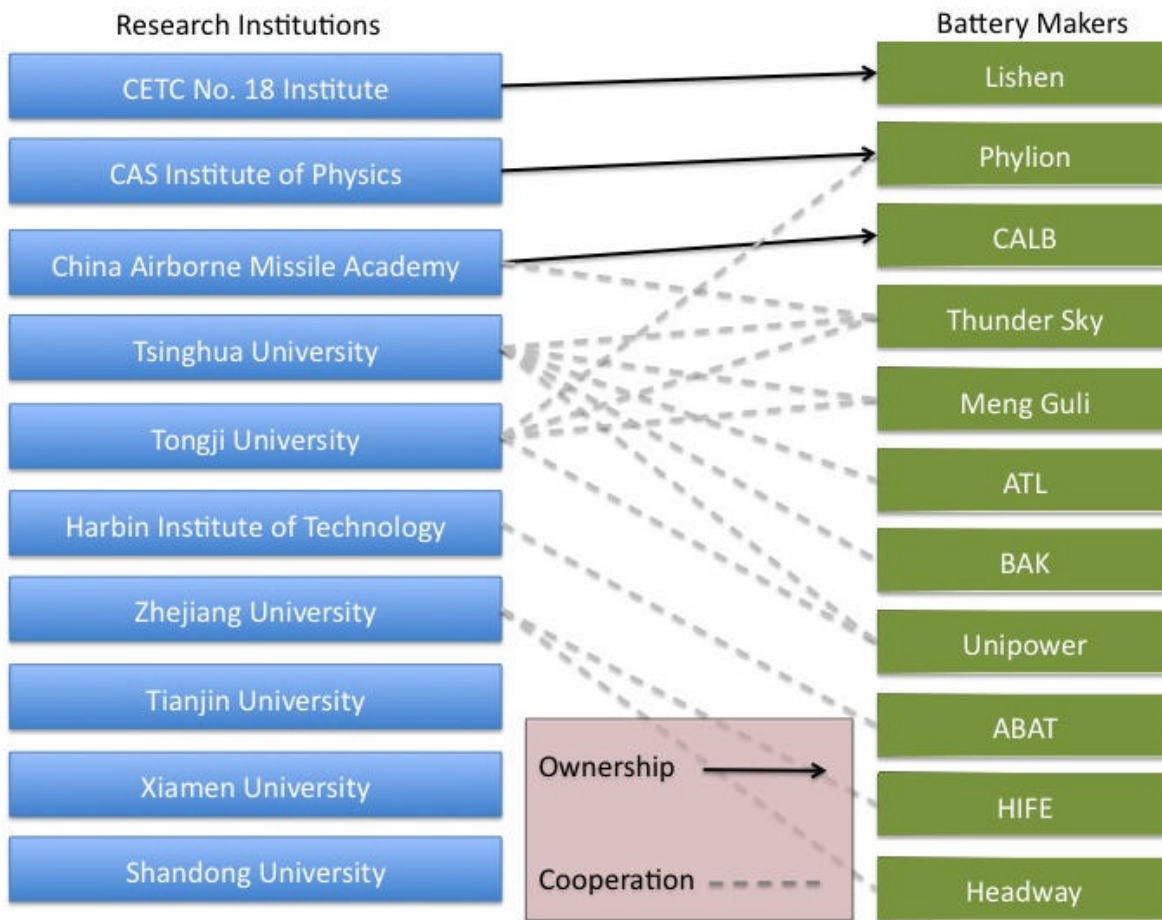
**Note:** 863 Programme refers to the National High-tech R&D Programme.

11. An area of battery production where China's industry is strong is cathode and anode materials. This is primarily because there is a sufficient supply of these raw materials. Furthermore, China can bring its expertise in consumer electronics batteries to bear here because production methods for lithium iron phosphate batteries are essentially the same as those for lithium cobalt oxide batteries, which are widely used in consumer electronics.<sup>3</sup>

12. China's weaknesses in high-performance battery production lay in electrolyte and separator materials, as well as in final cell and battery production. There are three causes for China's weakness in this area. First, these materials, responsible for energy regulation inside battery cells, are far more technically demanding because they require specialized chemistry or materials handling processes. At the time of writing, few companies can manufacture the  $\text{LiPF}_6$  salts required for electrolytes, and no companies in China manufacture the separator material for large batteries because of stringent quality requirements.

<sup>3</sup> China Greentech Initiative (2010). *Cleaner Transportation Sector Working Session #3* materials. p.44.

Figure 2

**Battery research institutes and technology sharing partnerships in China**

**Source:** China Greentech Initiative (2010). *Cleaner Transportation Sector Working Session #3.8* December 2010.

13. Second, China's battery industry has traditionally relied on hand-made battery cells. In single-cell batteries for electronics products, quality does not have to be guaranteed because each battery is relatively inexpensive and can be easily replaced. However, hand-made cells are less desirable for large multi-cell batteries where cells can only be replaced at great cost and where one bad cell will cause the entire battery pack to malfunction, causing safety and reliability problems. According to interviews, China does not yet have capacity to produce machinery for wrapping cells. At the time of writing of this report, China was investing heavily in machinery from Japan to automate the process of producing high-quality cells for use in transportation.

14. Third, China does not own significant intellectual property in the development of battery management systems which can help reduce the effects of the individual characteristics of each cell. Battery management systems work to balance the slight differences between cells in battery packs, but require complex algorithms and computing which Chinese industry and researchers still have not managed to develop for commercial use.

15. One reason for this lack of progress might be that in spite of China's well-organized and publicized announcements on research spending, its R&D spending on batteries falls well short of that of other major countries. The Republic of Korea has planned US\$342 million in EV battery R&D between 2009 and 2014 and up to US\$12.4 billion through 2020. Japan will spend at least US\$116 million through 2012. The US has budgeted US\$1.5 billion as part of the 2009 American Reinvestment and Recovery Act. Yet China has only allocated US\$26 million for the first three years of the 12<sup>th</sup> Five-Year Plan (2011-2015).

## **B. Electric vehicle development**

16. Electric vehicle development is happening for a broad variety of transportation modes. Broad commercialization started with electric bicycles, but spread to public buses, and is now occurring in personal vehicles and other vehicles such as municipal service vehicles, street sweepers, and other transportation tools.

### **1. Passenger vehicles**

17. Passenger vehicles are one of the major focuses of auto manufacturers in the electric vehicle sphere. Table 1 offers an overview of select Chinese automakers and their EV products at the time of writing, keeping in mind that for the most part, these vehicles are at the concept or testing stage. Figure 3 offers a comprehensive picture of the major automotive companies involved in the design and production of electric vehicles in China in 2010 and the supply relationships under development between battery manufacturers and vehicle manufacturers.

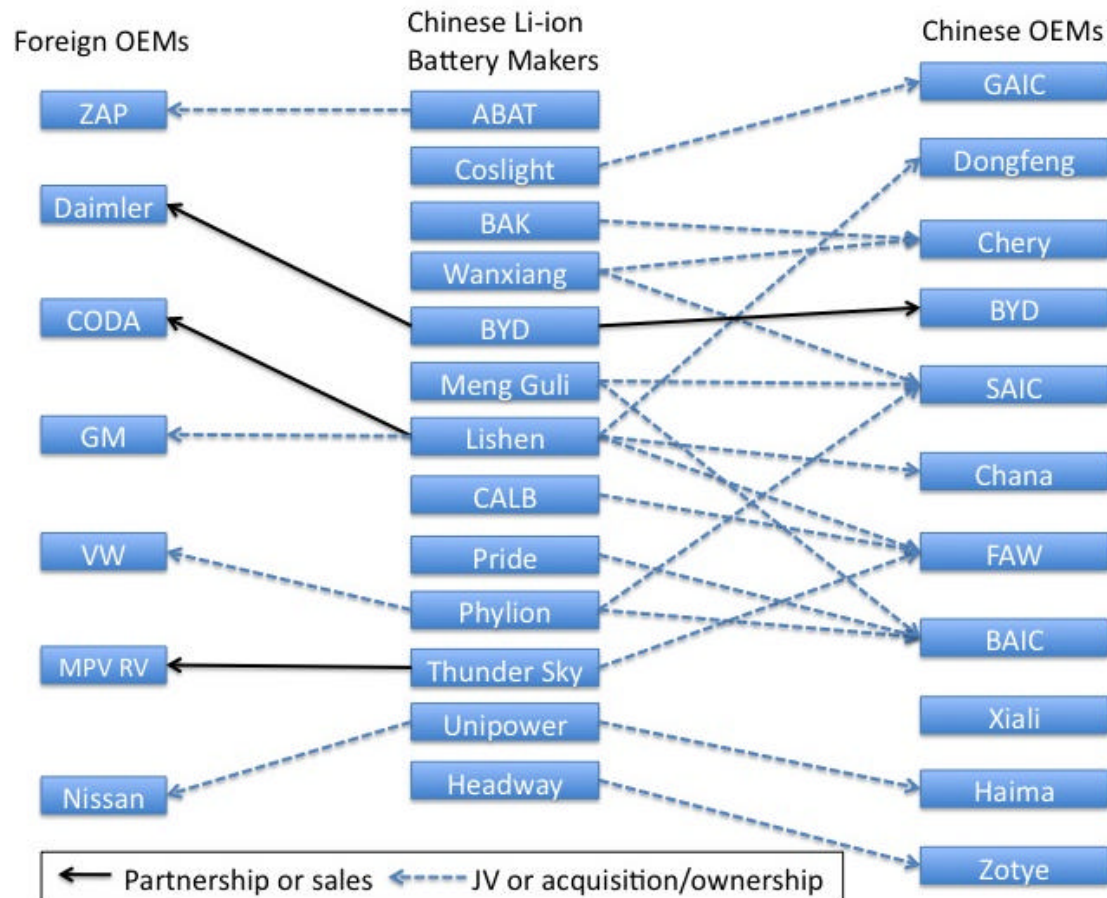
Table 1  
**Sample of Chinese manufacturers and EV model names**

<b>Manufacturer</b>	<b>EV Model Name</b>
BYD	E6
Chery	M1 EV, QQ3 EV
Chana	Benni EV-Chana
Zotye	5008 EV
Gonow	GA6380 EV
Haima	Freema EV
Lifan	620 EV, 320 EV
Great Wall Motors	ULLA

### **2. Electric buses and municipal vehicles**

18. At the Electric Vehicle Symposium 25 (EVS25), held in November 2010 in Shenzhen, over ten companies had fully electric buses on display demonstrating the Chinese industrial commitment to this technology. This development is based, in part, on two of the major demonstration projects that have taken place for electric buses in China thus far: the Beijing 2008 Olympic Games and the 2010 Shanghai World Expo.

Figure 3  
**Vehicle OEMs and battery makers in China - battery relationships**



Source: China Greentech Initiative and iCET.

19. The Beijing Olympic Games sported a fleet of 50 fully electric buses with battery exchange systems. These buses, manufactured by Jinghua Coach Company, had a range of about 130 km between battery swaps with air conditioning activated. In the meantime, the Shanghai Expo included demonstrations of a number of electric bus varieties. The most notable of the demonstrations was the 14 super capacitor buses at the Expo site, which were capable of fast-charging while waiting for passengers to get on and off the buses at bus stops.

20. Battery-electric buses have been one of the main focuses of the “Ten Cities, Thousand Vehicles”, a new energy vehicle demonstration programme, which is now being implemented across China and as a result have received a great deal of attention from manufacturers. Nearly all major bus producers have electric bus products in their lineups, most notably, Ankai Motors, having provided over half the existing on-road battery electric buses in the market. Foton and Jinghua are providing buses to Beijing. BYD is providing its new battery electric bus to Shenzhen and other cities.

21. Municipal vehicles other than public transport vehicles are also under consideration. Beijing city is planning to purchase a number of fully electric street sweeping vehicles and municipal waste collection vehicles as a pilot programme. These vehicles will be particularly suitable for electric power, as their routes are easily defined, cover a relatively small geographical area. Such programmes may offer marked reductions in urban air pollution.

### **3. E-bikes**

22. China is the largest producer and consumer of electric bicycles in the world. In 2009, China's production reached 23.69 million bicycles, and total population of electric bicycles reached over 120 million.<sup>4</sup> These vehicles, which primarily make use of lead-acid batteries, are proof that electricity is a viable source of energy for the transport sector in China. As electric bicycles become more popular in foreign markets, where higher prices are justified, manufacturers can begin shifting to lithium-ion batteries that are lighter but can bring more power to bear. In the coming years many electric bicycles in China will also use lithium batteries as costs are expected to decrease.

### **4. Low speed rural e-vehicles**

23. Another important type of electric vehicle found in China is the low-speed rural electric vehicle. These vehicles, powered by lead-acid batteries, are not officially licensed for use on roads, but have nonetheless seen production numbers of over 50,000 per year, with several factories, such as Shandong Shifeng and Tianjin Qingyuan, producing them across China. According to interviews, these low speed rural e-vehicles travel up to 60 km per hour, over distances of up to 80 km per charge, not unlike vehicles known as "Neighborhood Electric Vehicles" in the United States. The vehicles are manufactured by agricultural equipment firms, and are distributed along the same channels as agricultural vehicles. Since the main market is in rural communities, finding spaces for charging is not an issue, as most rural families live in single-family dwellings where there is room for parking and use of extension cords can ensure supply of power to vehicles to charge overnight. It is not known what the future for these vehicles will be. They may not receive government approval and are generally seen as low-tech transport solutions, which risk polluting the environment through improper disposal of lead-acid batteries.

### **5. Hybrids and plug-in hybrids**

24. Hybrid vehicles have been one of the focuses of the new energy vehicle project since 2001. After years of research and development, China has managed to grasp the key concepts for parts and motive systems of this technology and has manufactured a series of hybrid vehicle products. These products started with the joint-venture companies such as FAW-Toyota which manufactures the Prius, and now includes fully domestic models such as the FAW-Besturn HEV, SAIC-Rongwei HEV, Dongfeng Fengshen HEV, Chana's Jieshun, BYD's F3DM and others, indicating that Chinese hybrid vehicles have left the laboratory and entered the commercial market. With this development, there is expectation that this technology's market will develop

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<sup>4</sup> Available from [http://www.atimes.com/atimes/China\\_Business/LE07Cb01.html](http://www.atimes.com/atimes/China_Business/LE07Cb01.html)

quickly. The Development Research Center of the State Council of China forecasts that by 2013, hybrid car sales will reach 500,000 units per year and 1 million units per year by 2015.

25. Hybrid vehicles can receive five different levels of funding under China's "Ten Cities, Thousand Vehicles" new energy vehicle pilot programme. The highest subsidy amount is RMB 50,000, and hybrid vehicles usually qualify for a subsidy of RMB 42,000 – 50,000. Furthermore, as of June 2010, the Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology and the National Development and Reform Commission jointly issued a new subsidy policy, giving private buyers in Shanghai, Changchun, Shenzhen, Hangzhou and Hefei an extra subsidy for purchasing *plug-in* electric vehicles, either hybrid or pure electric. For every kW of battery capacity, a subsidy of RMB 3000 would be given to the buyer, giving PHEVs a maximum subsidy of RMB 50,000.

### **III. CHINA'S POLICY SUPPORT FOR ELECTRIFICATION OF TRANSPORT**

26. In industrialized countries, and in countries with rapidly growing industries, the phenomenon of electrification of transport is still one riled with debate. This debate is focused on the relative energy and capital efficiencies between efficient internal combustion engine vehicles (ICEVs), hybrid-electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs) and pure battery electric vehicles (BEVs), as well as the GHG emissions associated with all those technologies. In some ways, this debate has slowed the roll-out of advanced technologies. In China, however, a comprehensive pilot project process has been set in motion, supported by state funding and loans for technology development and subsidies for proliferation. Large-scale state-sponsored demonstration projects, supported by the National Development and Reform Committee (NDRC) and the Ministry of Science and Technology, accelerated development of electric vehicle technology.

#### **A. The Ministry of Science and Technology and the "863 Programme"**

27. The development of an electric bicycle and vehicle industry has been in the sight of the Ministry of Science and Technology since at least 2001, when the "863 Electric-Drive Fuel Cell Vehicle Project" received an initial investment of RMB 800 million.

28. A key funding mechanism for research in the research and application of new technology in China is the State High-Tech Development Plan, also known as the "863 Programme" (named as such for having been founded and finally endorsed by Deng Xiaoping in the third month of 1986). In recent years, this fund has mostly supported the development of electric vehicles.

**Box 1****Electric Vehicle Policy Support in China: A Timeline**

**2001:** *863 Electric Fuel Cell Vehicles Project* – Government investment of RMB 800m.

**2006:** *863 Energy-Saving and New Energy Vehicles Project* – MOST invests RMB 1.1 bn, setting technology roadmap for the EV industry

**2008:** MOST, MOF, NDRC and MIIT<sup>5</sup> – *1000 Vehicles, 10 Cities Demonstration Project*

**2009:** State Council – *Plan on Adjusting and Revitalizing the Auto Industry* – Planned to invest RMB 3bn to develop key EV technology

**2010:** MOST, MIIT and MOF – *Subsidy Standards for Private Purchase of New Energy Vehicle* – selected 5 cities for private EV purchase subsidy with RMB 50,000 maximum subsidy for PHEV, RMB 60,000 for BEV.

**2010:** *863 Key Technology and System Integration Project for Electric Vehicles* – RMB 738 m for battery and EV integration with 42 per cent of funds for battery research

**Box 2****The “Ten Cities, Thousand Vehicles” New Energy Vehicle Demonstration Project**

Unique to China is its focus on systematic demonstrations of electric vehicle technologies in a number of cities across the country. The “Ten Cities, Thousand Vehicles” (TCTV) project, born in 2008, springs out of the modern Chinese tradition of implementing various approaches to new technologies in different places on a pilot basis, then replicating successful demonstrations across the country.

In early 2009, Ministry of Finance, National Development and Reform Commission, Ministry of Industry and Information Technology and the Ministry of Science and Technology listed Beijing, Shanghai, Chongqing, Changchun, Dalian, Hangzhou, Jinan, Wuhan, Shenzhen, Hefei, Changsha, Kunming, and Nanchang as the first 13 energy saving and new energy vehicle demonstration cities; in June 2010, 7 more cities were added: Tianjin, Haikou, Zhengzhou, Xiamen, Suzhou, Tangshan, and Guangzhou; finally, in July 2011, the program was expanded to 25 cities, including Shenyang, Chengdu, Nantong, Xiangfan and Hohhot. In these 25 cities, public service vehicles receive significant national government subsidies. Shanghai, Changchun, Shenzhen, Hangzhou, and Hefei are the first 5 pilot cities which offer subsidies for private electric and other new energy vehicle purchases.

<sup>5</sup> MOST - Ministry of Science and Technology ; MOF - Ministry of Finance; NDRC- National Development and Reform Commission; MIIT - Ministry of Industry and Information Technology

## **B. Bilateral cooperation in electric vehicle development**

29. While electric vehicle development is a strategic focus in China, it is also a major focus of interest and development in other regions. Bilateral cooperation is an important driver for China as it seeks new technology, develops markets and ensures the development of a vehicle market that both meets and sets global standards. Aside from commercial collaboration, there are two major bilateral partners that China is cooperating with in the area of electric vehicles.

### **1. United States**

30. The US, formerly the largest vehicle market in the world and still stringent leader in safety and quality regulations, is a natural partner. China, with its export-oriented manufacturing sector, has plans for exporting electric and ICE vehicles, parts, batteries and other components to the US. In the meantime, the US is a key developer of technology and world leader in technical modeling of vehicles, vehicle use and other key technologies.

31. The US and China have created the US-China Clean Energy Research Center (CERC) which focuses on three areas: clean coal, “green” buildings, and clean vehicles. The clean vehicles component is led by the US Department of Energy and the Chinese Ministry of Science and Technology. Tsinghua University’s State Laboratory on Automotive Safety and Energy leads the technical aspect of the project, with a large number of academic and corporate partners. Likewise, the US research partnership is led by the University of Michigan, with other research centers and vehicle manufacturers involved. The goal of the center is to identify collaborative development opportunities between the US and China and build a long-term relationship in these fields.

32. There are also other academic and commercial collaborative efforts between the US and China, including project development with the University of California at Davis and Tongji University, US-China joint ventures such as ZAP/Jonway and CODA/Lishen based in California. California has been a test bed for a number of Chinese electric vehicles including cars and buses.

### **2. Europe**

33. Europe, another key innovative automotive power, is the other obvious bilateral collaborator for China in the development of electric vehicles. Currently, the China Automotive Technology and Research Center is deepening ties with Germany in a number of research projects such as the “Mini-e” electric vehicle market research study in China. Volkswagen is promoting its e-Golf in Beijing, and the German organization, Gesellschaft für Internationale Zusammenarbeit (GIZ, a merger of GTZ and two other companies) is supporting energy consumption standard development with the China Automotive Technology And Research Center (CATARC).

#### **IV. LIFE-CYCLE RAW MATERIAL ASSESSMENT, ENERGY USE AND GHG EMISSIONS FOR ELECTRIC VEHICLES**

34. An important part of the discussion about advantages of electric vehicle implementation both in China and around the world is the opportunity for reducing dependence on fossil fuels, and taking advantage of the inherent energy efficiency of electric motors to reduce air pollution and the emission of greenhouse gases into the atmosphere. This section will analyze the impact of electric vehicle manufacturing on raw material consumption, and the potential impact of pure electric vehicles on GHG emissions.

##### **A. Impact of EV development on raw materials**

35. There are two primary categories of raw materials that need to be considered in the switch from ICE to electric vehicles: lithium (the favorite for battery technology in the near and mid-term), and rare earth metals, used in motors, generators and nickel metal hydride batteries.

##### **1. Lithium**

36. Access to and technologies regarding lithium are extremely important in the future of EVs. Most battery technologies currently under commercial consideration are based in some way on lithium-ion, specifically because of its applicability in both HEVs and BEV, its high energy density, and relatively low cost. Commercially available lithium is found in underground brines, deposits found globally. The largest producer is Chile, followed by Australia. China, the world's third largest producer, is ramping up production in advance of its expected huge demand based on the policy push to develop electric vehicles.<sup>6</sup> It is believed that in order to supply enough batteries to China's electric vehicles targeted in 2012, 50,000 tons of lithium carbonate will need to be supplied annually.<sup>7</sup>

37. The global production of electric vehicles is not expected to be limited by global lithium supply. Although some analysts fear that lithium production will be much smaller than expected and at much greater expense (Meridian International Research), the broader consensus seems to be that lithium is a plentiful resource that, given the current demand and possibilities for recycling, will supply this sector for decades to come (e.g. Electrification Coalition, Argonne National Labs, etc.).

38. China's main production of lithium is in Qinghai province, in western China, where approximately 6,000 tons of lithium carbonate were extracted in 2009. Qinghai expected to increase production in the province to 30,000 tons per year by 2015 to cope with demand, with 83 per cent of production coming from Citic National Security Lithium Technology Corp. and Qinghai Lithium Corp. This, however, is reduced from a target of 60,000 tons, a manifestation of technology limitations in the region.<sup>8</sup> China's target for 500,000 electric vehicles on the road

<sup>6</sup> Electrification Coalition. 2009. *Electrification Roadmap: Revolutionizing Transportation and Achieving Energy Security*. pp. 82-83.

<sup>7</sup> China Greentech Initiative. 2010. *Cleaner Transportation Sector Working Session #3 materials*. p. 43.

<sup>8</sup> Brown, Dave. China Revises Overly Ambitious Lithium Production Forecasts. August 4, 2010. *Lithium Investing News*. Available from <http://lithiuminvestingnews.com/1750/china-revises-overly-ambitious-lithium-production-forecasts/> Last accessed on 5 January 2011.

by 2012 will require the use of 50,000 tons of lithium carbonate to be produced, indicating the need to develop new resources.

## 2. Rare Earth Metals

39. Rare earths are another important category of resources that will be affected by the production of large numbers of electric vehicles. Rare earths are used in powerful hard magnets in electric motors and generators, both of which are used in electric vehicles. Furthermore, particularly in the Nickel Metal Hydride batteries used in hybrid vehicles, rare earths such as lanthanum are used as battery electrodes. It has been reported that the battery of a Toyota Prius hybrid vehicle uses 10-15 kg of lanthanum in its battery.<sup>9</sup>

40. China is thought to possess about 30 per cent of the world's reserves of rare earths, but produces around 95 per cent.<sup>10</sup> The production of these resources has been criticized as being heavily polluting to the environment, specifically causing significant air and water pollution in production facilities where there is little environmental regulation. However, in light of these environmental impacts, the Chinese Ministry of Environmental Protection has recently released new draft industry standards that aim to reduce pollution and regulate practices by rare earth mining companies. Under the proposed standards, the permissible amount of pollutant in a liter of waste water from production should contain less than 15 mg of ammonia nitrogen, amongst other standards.<sup>11</sup>

### B. GHG emission analysis

41. A number of studies have been conducted on the potential lifecycle GHG emission changes due to the replacement of conventional Internal Combustion Engine (ICE) vehicles by plug-in hybrid electric vehicles and pure battery electric vehicles. A 2007 report by US-based Electric Power Research Institute and Natural Resource Defense Council suggested that in the US, even with high electric sector CO<sub>2</sub> intensity, and low penetration of plug-in hybrid electric vehicles, there would be significant avoidance of GHG emissions in 2050.<sup>12</sup> They estimated that GHG emissions could be reduced by 160 Mt CO<sub>2</sub> per year (low scenario; old coal and low market penetration) to 612 Mt (low CO<sub>2</sub> intensity and high market penetration) and cumulative reductions of 3.4 Gt to 10.3 Gt, respectively.<sup>13</sup>

42. In energy efficiency, research from the Massachusetts Institute of Technology suggests that BEVs, with their oversize batteries are not as efficient as PHEVs in converting on-board stored energy to motive energy, but still demonstrate dramatic improvements over both ICE vehicles both now and what the researchers expected in 2035 (Figure 4).<sup>14</sup>

<sup>9</sup> Buckley, Chris. Reuters. *China's Dream for Rare Earths Rests on Grim Costs*. 4 November 4 2010. Available from <http://www.reuters.com/article/idUSTRE6A13B520101103>. Last viewed January 7, 2011.

<sup>10</sup> Available from <http://www.nytimes.com/2010/11/20/business/global/20rare.html>

<sup>11</sup> Ministry of Environmental Protection (2010). Rare Earths Industrial Pollution Emission Standards China National Standard GB26451-2011). Available from <http://www.mep.gov.cn/gkml/hbb/bgg/201101/W020110210363692022222.pdf>

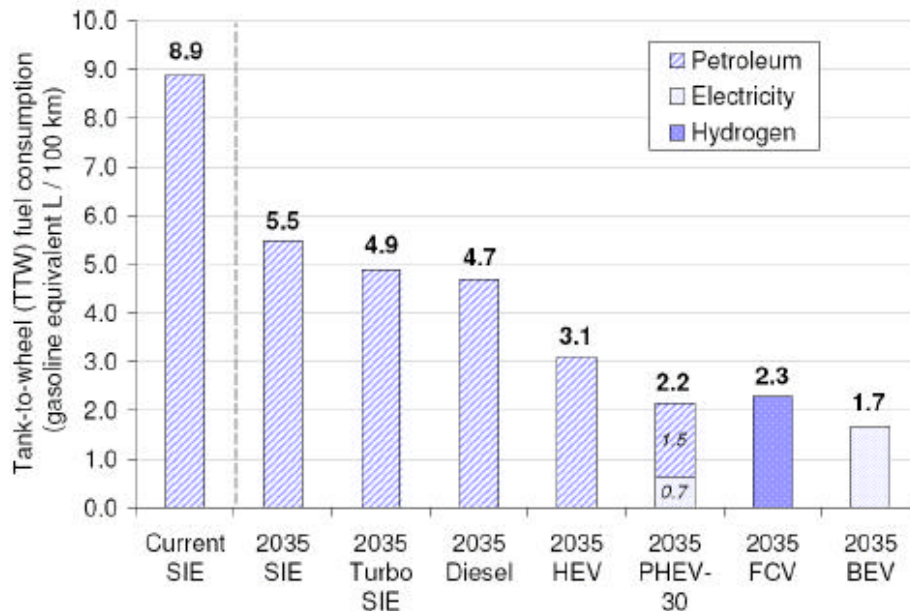
<sup>12</sup> Electric Power Research Institute, Natural Resources Defense Council & Charles Clark Group (2007). Environmental Assessment of Plug-In Hybrid Electric Vehicles. Volume 1: Nationwide Greenhouse Gas Emissions. Available from <http://my.epri.com/portal/server.pt? Abstract id=00000000001015325>. Accessed on 30 December 2010.

<sup>13</sup> *Ibid.* p. 5-10.

<sup>14</sup> Bandivadekar, A., K. Bodek, et. Al (2008). On the Road in 2035: Reducing Transportation Petroleum Consumption and GHG Emissions. Laboratory for Energy and the Environment, Massachusetts Institute of Technology.

Figure 4

### Tank-to-wheel fuel consumption of various vehicle technologies in 2035 compared to present technology



Source: *Ibid.* p. ES-4.

Note: SIE refers to spark-ignited internal combustion engine.

43. But for GHG emissions, there is a different story for BEVs and PHEVs. Figure 5 demonstrates that vehicles that use electricity from the grid have varying GHG emissions. While the average well-to-wheel emission value for BEVs in 2035 was lower than all the non-hybrid fossil fuel powered vehicles, the fact is that given the different sources of electricity on different grids, GHG emissions from BEVs can be even higher than those of conventional gasoline powered ICE vehicles in 2035 (assuming a heavy reliance on old coal technology).<sup>15</sup>

44. While there have been a number of studies conducted on the implications of US and EU development of EV on GHG emission and energy consumption, few studies have been conducted in China. One study<sup>16</sup>, completed by researchers at Tsinghua University and Argonne National Labs analyzed GHG emissions and other emissions based on the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model. This research also found vast differences in emission reduction potential of electric vehicles based on the grid from which an electric vehicle was charged,<sup>17</sup> demonstrating that only on the South China grid do GHG emissions per km traveled fall beneath the emissions of HEV vehicles. In fact, hypothetical vehicles on the Northeast China grid and North China grid, both heavily dependent on coal-fired electricity, would see increased GHG emissions.

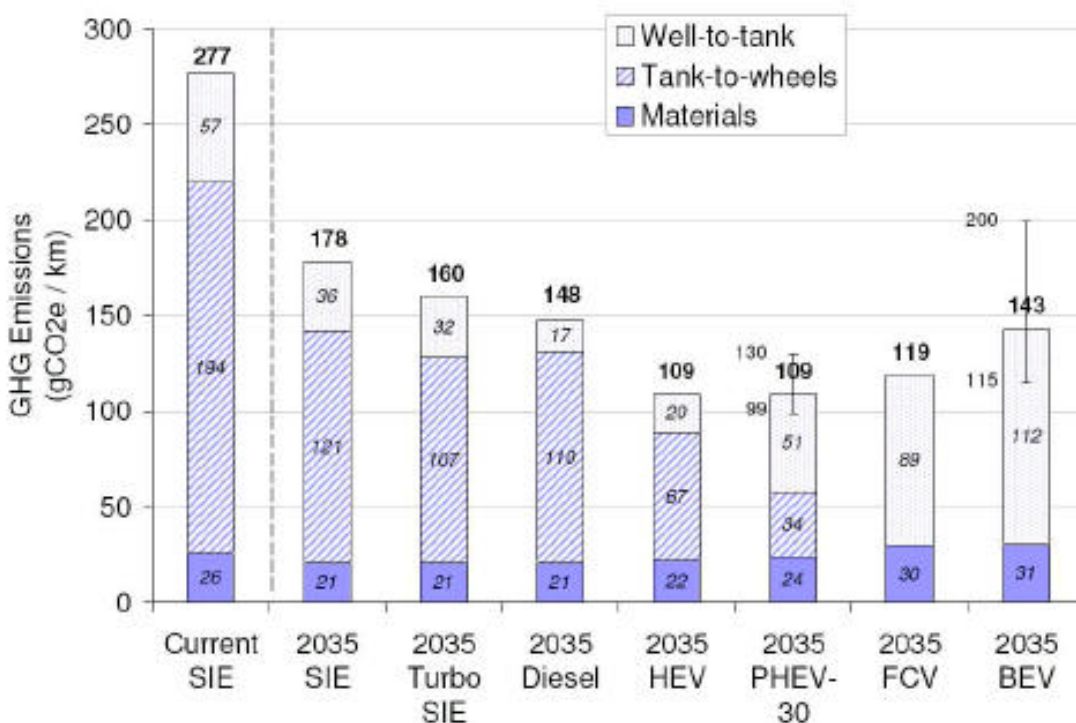
<sup>15</sup> *Ibid.* p. ES-4.

<sup>16</sup> Huo, H., Q. Zhang, M. Wang, D. Streets and K. He. (2010). *Environmental Implication of Electric Vehicles in China*. *Environmental Science and Technology*. 44 (13), pp 4856–4861.

<sup>17</sup> *Ibid.* p. 4857.

Figure 5

**Well-to-wheel GHG emissions per km from various vehicles drive technologies in 2035 compared to present gasoline ICE technology**



Source: *Ibid.* p. ES-4.

Note: Vehicles that use grid electricity have a range of emissions per km due to differing energy mixes.

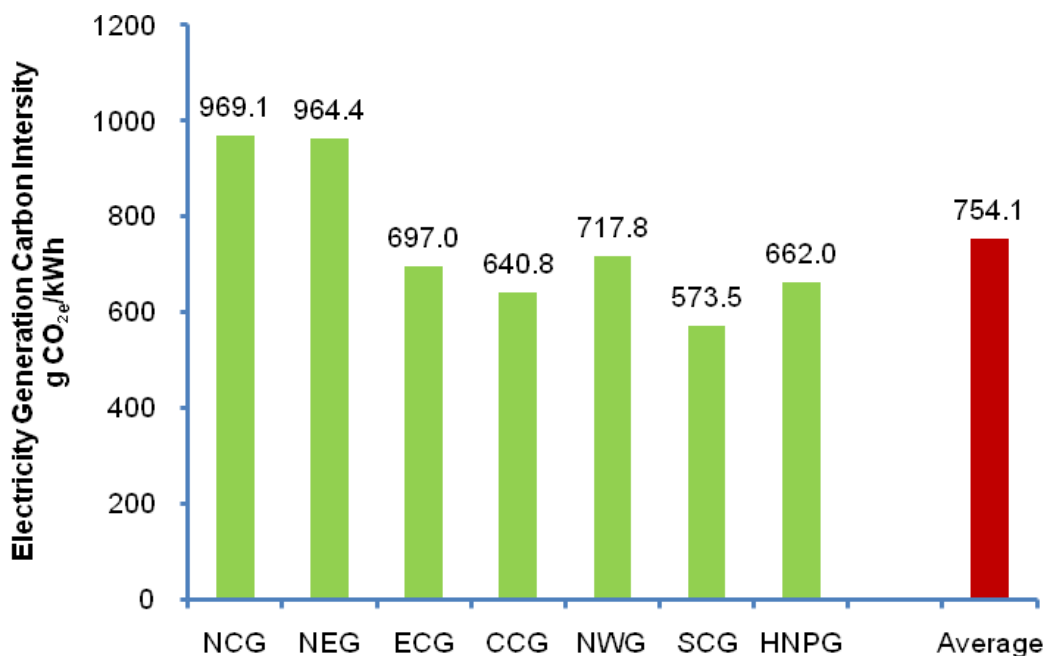
45. For the present report, we have undertaken our own analysis of potential GHG emission reductions, based on the reported carbon intensities of China's seven electrical grids, independent research on key energy consuming parts of the electrical supply chain.

### C. Case Study: On-road electric vehicles in China – GHG emission reduction potential

46. This case study aims to demonstrate the GHG emission reduction potential of putting a small number of EVs on the road in China. China, like other countries, supplies its electricity through a number of interconnected electric grids. China has six major regional grids, plus one small grid for the island of Hainan. Figure 6, below, indicates the geographical distribution of each grid, and gives an indication of the electrical mix of each grid.

Figure 6

**Electricity Generation Carbon Intensity Values of regional power grids in China  
(Emissions from power plants)**



**Notes:** NCG – North China Power Grid; NEG – Northeast China Power Grid;  
ECG–East China Power Grid; CCG- Central China Power Grid;  
NWG- Northwest China Power Grid; SCG- South China Power Grid;  
HNPG- Hainan Power Grid

47. Energy supply from power generation in China relies on coal, for more than 80 per cent. Hydroelectricity is the second-largest power energy source, at about 16 per cent. Nuclear, wind, biomass and other power sources are basically small supplements at this time. Furthermore, the power energy resources are distributed unevenly, with the Central China Grid, renewable electricity levels reaching up to 40 per cent, with renewable energy in the North China Grid at less than 2 per cent. Electricity production of each regional grid in 2008 is noted in Table 2.

Table 2  
Electricity production from major Chinese regional grids (units of 100 GWh)

Regional Power Grid	Thermal		Hydro		Nuclear		Wind and other		Total (and % of total China power production)	
<b>North China</b>	8217	98.80%	50	0.60%	0	0.00%	52	0.60%	8320	24.9%
<b>Northeast China</b>	2259	94.00%	103	4.30%	0	0.00%	40	1.70%	2402	7.2%
<b>East China</b>	6989	87.70%	514	6.40%	373	4.70%	95	1.20%	7971	23.8%
<b>Central China</b>	3628	58.70%	2542	41.10%	0	0.00%	8	0.10%	6178	18.5%
<b>Northwest China</b>	2131	77.60%	597	21.70%	0	0.00%	18	0.70%	2747	8.2%
<b>South China</b>	3665	64.40%	1709	30.00%	311	5.50%	7	0.10%	5691	17.0%
<b>Hainan</b>	104	88.80%	12	10.20%	0	0.00%	1	1.00%	118	0.4%
<b>Total</b>	<b>26993</b>	<b>80.80%</b>	<b>5526</b>	<b>16.50%</b>	<b>684</b>	<b>2.00%</b>	<b>222</b>	<b>0.70%</b>	<b>33424</b>	<b>100.0%</b>

Source: State Statistical Bureau of China. Electricity Year Book of China 2009. China Statistics Press: Beijing, China, 2009.

48. The emission factor (or carbon intensity) of the electricity produced on each regional power grid varies depending on energy source and generation efficiency. The China Clean Development Mechanism Center publishes the Baseline Emission Factors for regional power grids in China, including the GHG emission values, taking into account the generation stage GHG emission.

49. Overall, the emission factors for renewable energy are very low – perhaps only 1 per cent of carbon GHG emission factor of coal-fired electricity, and gas and petroleum-fired electricity occupies a very small segment of electricity produced as well. As a result, 97.5 per cent of GHG emissions from the production of electricity are from coal. Natural gas makes up 1.9 per cent of the emission profile, and petroleum 0.6 per cent.

50. GHG emissions related to electricity come from each step of the production and use chain, from extraction of coal, to power production, to the efficiency of final use. It is important to take into account the total lifecycle emissions from the electricity used for transportation in order to make a fair comparison to the GHG emissions from vehicles that burn petroleum fuels.

Table 2  
**Electricity generation, carbon intensity and total GHG emissions of regional grids in China (2008)**

<b>Regional Power Grid</b>	<b>Electricity Production<sup>18</sup> (100 GWh)</b>	<b>GHGs Emission<sup>19</sup> (Million Tons)</b>	<b>Carbon Intensity (gCO<sub>2e</sub>/kWh)</b>
<b>North China</b>	8320	806.2	969.1
<b>Northeast China</b>	2402	231.6	964.4
<b>East China</b>	7971	555.6	697.0
<b>Central China</b>	6178	395.9	640.8
<b>Northwest China</b>	2747	197.1	717.8
<b>South China</b>	5691	326.4	573.5
<b>Hainan</b>	118	7.8	662.0
<b>Average</b>			<b>754.1</b>

**Source:** China Clean Development Mechanism Center.

51. *Lifecycle* GHG emissions need to take into account GHG emission from each stage of the energy production and use cycle, including Primary Energy Fuel Extraction and Transport, Electricity Production, Electricity Transmission and Distribution, Charging Efficiency, and Battery-to-Wheel Efficiency. The first two stages can be categorized as “Mine-to-Plant” emissions, and all of the above stages with the exception of the last one can be categorized as “Mine-to-(Battery)Pack” emissions. Most automakers are used to claim their EV ratings focusing only on the Battery-to-Wheel efficiency.

#### **D. Primary energy fuel extraction and transport**

52. Coal combustion accounts for the majority of emissions in the electric power sector – 97.5 per cent. According to Ou Xunming (2010)<sup>20</sup> and Song Lingjun (2010)<sup>21</sup>, the factor for emissions from coal mining, processing and transportation is approximately 5 per cent of thermal energy production. Figure 7 illustrates the emission factors of the seven regional grids including the mine-to-plant segment of the fuel chain.

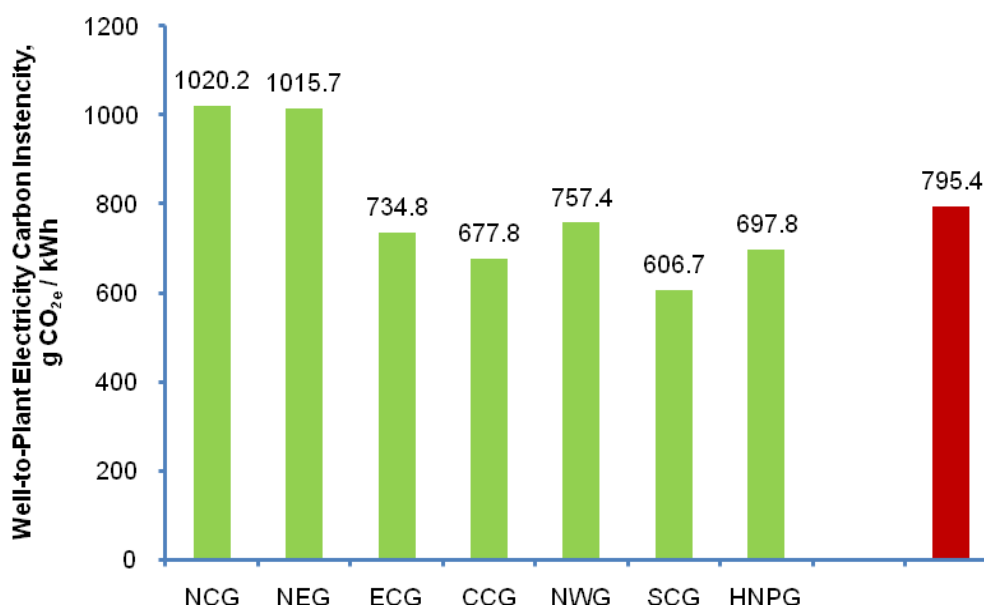
<sup>18</sup> State Statistical Bureau of China. Electricity Year book of China 2009. China Statistics Press: Beijing, China, 2009.

<sup>19</sup> NDRC. 2010 Baseline Emission Factors for Regional Power Grids in China. Available from <http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2551.doc>

<sup>20</sup> Ou Xunming, Yan Xiaoyu, Zhang Xiliang. Life-cycle energy consumption and greenhouse gas emissions for electricity generation and supply in China. Applied Energy 88(2011):289-297

<sup>21</sup> Song Linjun, Wang Hewu, Ouyang Minggao. Life cycle analysis of coal-fired power generation in China. EV25, Shenzhen, 2010. Nov.5-9

Figure 7

**Mine-to-plant and generation emission factors for China's regional power grids (2008)****E. Transmission and distribution losses, charging efficiency and battery efficiency**

53. Transmission and distribution (T&D) of electricity is not a process without losses. Electricity Industry Statistics, an internal State Grid publication, indicates that average electricity T&D loss was 6.64 per cent in 2008.<sup>22</sup> Charger efficiency loss ranges from 10-13 per cent, depending on the voltage and type of the chargers.<sup>23</sup> We assumed that the voltage of charging would be relatively high in China, and assumed a loss of 12 per cent. Meanwhile, losses from the battery itself (through heat loss) amount to 3-5 per cent.<sup>24</sup>

54. Therefore, the overall efficiency of the power transmission and charging process should be equal to 93.6 per cent (T&D) × 88 per cent (charger efficiency) × 96 per cent (battery-in efficiency) = 79 per cent efficiency in total.

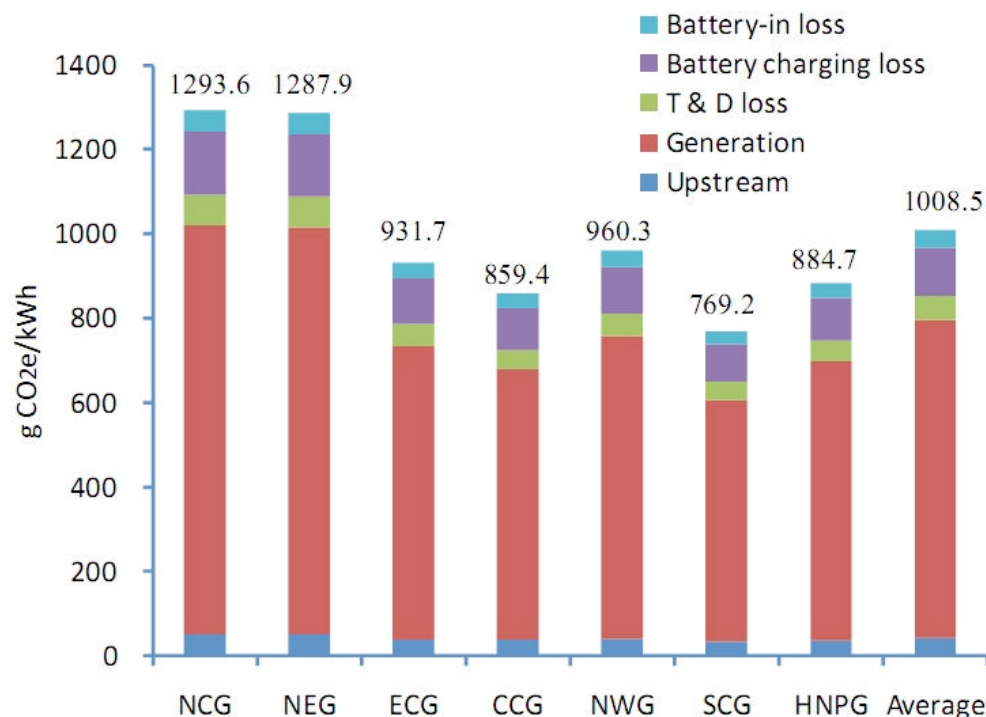
55. Given this information, it can be found that the North China power grid provides the most carbon intense electricity when used by BEVs, at 1293.6 gCO<sub>2e</sub>/kW-h, on a life-cycle basis. In order of decreasing carbon intensity, next is the Northeast power grid (1287.9 gCO<sub>2e</sub>/kW-h), Northwest power grid (960.3 gCO<sub>2e</sub>/kW-h), East China power grid (931.7 gCO<sub>2e</sub>/kW-h), the Hainan power grid (884.7 gCO<sub>2e</sub>/kW-h), Central China power grid (859.4 gCO<sub>2e</sub>/kW-h), and finally, the South China power grid at 769.2 gCO<sub>2e</sub>/kW-h. The power production weighted average of the Chinese electrical supply, on a “Mine-to-Pack” basis, is 1008.5 gCO<sub>2e</sub>/kW-h.

<sup>22</sup> 2008 Electricity Industry Statistics Express. Internal material from State Grid. Personal communication from Zhang Shuwei.

<sup>23</sup> Personal consultation to Argonne National Laboratory distinguished electric expert Dr. Anantray D. Vyas.

<sup>24</sup> Personal consultation to Argonne National Laboratory distinguished electric expert Dr. Anantray D. Vyas.

Figure 8

**“Mine-to-Pack” (Well-to-Tank equivalent) GHG intensity of regional power grids (2008)**

56. Based on the calculations above, GHG multipliers can be developed for the energy consumption ratings of electric vehicles. This is to say that in the energy consumption rating, for each increase of 1kWh/100 km, the GHG emission will increase by a certain amount, depending on the grid where the vehicles is charged. The multiplier is a unitless value. The multipliers are in Table 4 below.

Table 4

**GHG emission multiplier for energy consumption rated electric vehicles in China (to use, multiply vehicle label energy consumption by multiplier)**

Regional Power Grid	GHG Emission Multiplier
North China	12.94
Northeast	12.88
East China	9.32
Central China	8.59
Northwest China	9.60
South China	7.69
Hainan	8.84

## 1. Emission reduction potential of electric vehicles in China

57. It is essential to compare the energy consumption of electric vehicles with the energy consumption of internal combustion vehicles on a fair basis: that is, on a full fuel lifecycle emissions assessment basis. It is assumed that every liter of gasoline burned in an engine will produce 2.38 kg of CO<sub>2</sub>e<sup>25</sup>. However, this does not include the emissions of extraction and refining of crude oil, which have been calculated to be approximately 18 per cent of the total lifecycle GHG emissions<sup>26,27,28</sup>. The resulting total WTW emission of 2.92 kg of CO<sub>2</sub>e per litre of gasoline. Therefore, the multiplier to calculate GHG emissions from ICE vehicles in China is 29.2 kg of CO<sub>2</sub>e.

## 2. Lifecycle GHG emission changes from EVs replacing ICEVs

58. Given China's EV promotion policies, it is no surprise that there is a relatively large range of electric vehicles both on the road on a pilot basis, as well as in the showroom apparently ready for mass production in China. Table 5 indicates some of these model names as well as their ICEV equivalent vehicles, those being ICE vehicles of a similar class or model as the electric vehicle proposed.

Table 5  
Ten electric vehicles from Chinese manufacturers and their ICE model equivalents

Order	EV type	Manufacturer Reported Energy Consumption (kWh/100km)	ICEV	Fuel Consumption (L/100km)
1	E6-BYD	21	M6-BYD	9.8
2	M1 EV-Cherry	14	M1-Cherry	6.5
3	Benni EV-Chana	10	Benni-Chana	5.8
4	QQ3 EV-Cherry	12	QQ3-Cherry	6.0
5	5008 EV-Zotye	12	5008-Zotye	7.1
6	GA6380 EV-Gonow	16	GA6380-Gonow	7.2
7	Freema EV-Haima	16	Freema-Haima	8.4
8	620 EV-Lifan	15	620-Lifan	7.6
9	320 EV-Lifan	16	320-Lifan	6.4
10	ULLA-GWM	10	PERI-GWM	6.7

**Notes:**

1. EV data is unofficial. ICEV data is officially reported data.
2. Energy consumption listing for EVs is listed on their manufacturers' websites. These values are in no way

<sup>25</sup> Jin, Yuefu and Zhao Wang (2010). Research and Formulation of Standards for Fuel Consumption of Passenger Cars in the Next Stage. Tianjin: China Automotive Technology and Research Center (CATARC). P. 63.

<sup>26</sup> International Council on Clean Transportation (ICCT). December 2010. Carbon Intensity of Crude Oil in Europe Crude.

<sup>27</sup> US Environmental Protection Agency (2009). Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Proposed Rule. 40 CFR Part 80 [EPAHQ-OAR-2005-0161; FRL-8903-1], RIN 2060-A081. Assessment and Standards Division, Office of Transportation and Air Quality. Available from [www.epa.gov/OMS/renewablefuels/rfs2\\_1-5.pdf](http://www.epa.gov/OMS/renewablefuels/rfs2_1-5.pdf).

<sup>28</sup> European Commission (2009). Consultation paper on the measures necessary for the implementation of Article 7a(5). Available from <http://ec.europa.eu/environment/air/transport/pdf/art7a.pdf>.

standardized, but are used as a source of somewhat “real world” data, as compared to data from models such as GREET.

3. ICE vehicle data is from Ministry of Industry and Information Technology of the People’s Republic of China. 2010 Online database: Light-duty vehicle fuel consumption notice. Report date: 28 December 2010. Available from <http://gzly.miit.gov.cn:8090/datainfo/miit/babs2.jsp>. Last accessed on 5 January 2011.

59. It should be noted that it is still not possible to really compare the EV performance or efficiency rating because many of these models are only at the concept car phase. There is currently also no standardized test cycle for electric vehicles in China. Thus, energy consumption ratings for EV’s have no basis for comparison as the methods for generating these data are unknown.

60. Globally, at the time of writing, the only fully electric vehicle with an energy consumption rating generated from a standardized test cycle is the Nissan Leaf in the US. Nissan has indicated that it will launch the Leaf in China in 2012, so this research will use US energy consumption values for the Leaf as the comparison vehicle in this case study. The equivalent vehicle for comparison of GHG emissions is the vehicle marketed in China as the Nissan Tiida (Table 6). The Tiida has a similar body and chassis to the Leaf, and we have assumed that it can offer comparable user experience. We selected two models which meet the *Light-duty Vehicle Emission Limit IV* (Known as Euro IV or China IV standards – GB 18352.2-2005) in the Ministry of Industry and Information Technology Light Passenger Fuel Consumption Database, one with automatic transmission (AT), and the other with manual transmission (MT).<sup>29</sup>

Table 6  
**Nissan Leaf and typical Nissan Tiida descriptive parameters**

Vehicle	Leaf	Tiida-AT	Tiida –MT
Type	EV	ICEV	ICEV
Typical Model	---	DFL7161AC	DFL7161MAK
Fuel consumption kWh(L)/100km	21.1	7.3	6.5
Curb weight, kg	1525	1182	1160
Max Power, kW	80	80	80
Max Torque, Nm/rpm	280/2730	153/4400	153/4400
Displacement, ml	---	1598	1598
Emission standard	---	China IV	China IV
Transmission	AT	AT	MT

61. Based on the regional differences in emissions from the electric grid, this scenario set out to discover what the change to GHG emissions would be if a small number of gasoline ICE vehicles were replaced by grid-connected electric vehicles.

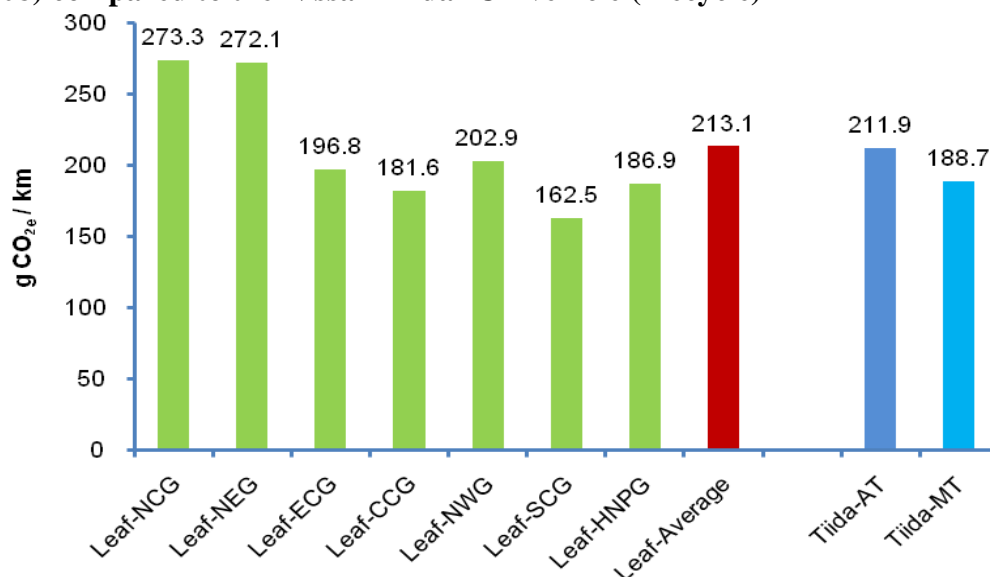
62. In our analysis, the Nissan Leaf lifecycle GHG emission, based on a 21.1 kWh/100 km rating, ranges from 162 gCO<sub>2</sub>e/km to 273 gCO<sub>2</sub>e/km depending on which grid it is charged. The

<sup>29</sup> MIIT.Light passenger vehicle fuel consumption announcement. Available from <http://gzly.miit.gov.cn:8090/datainfo/miit/babs2.jsp>; Accessed on 11 January 2011.

national average on an electricity production weight basis was 213 g/km. In the meanwhile, the Tiida (AT) lifecycle GHG emission on a 7.3 L/100 gasoline consumption rating is 212 g/km, and 189 g/km for the MT model. Based on these figures, GHG emission changes range from a 23 per cent reduction to a 36 per cent *increase* over the use of ICE vehicles.

Figure 9

**Well-to-Wheel carbon intensity of the Leaf based on various regional power grids of China (2008) compared to the Nissan Tiida ICE vehicle (lifecycle)**



### 3. Greenhouse gas emissions and the promotion of electric vehicles in China

63. Based on the conclusions of our analysis, it is clear that from a GHG emission reduction perspective, EVs should not be promoted in cities on the North China power grid and Northeast China power grid. Cities including Beijing, Tianjin, Tangshan, Dalian, Shenyang, Changchun and Hohhot will see increased emissions through the replacement of ICE vehicles with electric vehicles. In the other regions, however, vehicles could make a contribution to reduction in urban air pollution.

## V. CONCLUSIONS AND RECOMMENDATIONS: ENHANCING THE SUSTAINABILITY OF ELECTRIC VEHICLES

64. It has been assumed, not only in China, but around the world, that electrified transport is an environmentally friendly technology if compared to other transportation energy options. However, there is a growing body of evidence, including in this paper, that suggests that under current conditions, pure battery electric vehicles may not always improve environmental impact of transport as much as we would like to expect; in fact, in some regions, electric vehicles are not an environmentally friendlier technology, particularly in terms of GHG emissions, because of the source of electricity which powers them.

65. The range of impact that BEVs have on the environment leads us to conclude that this technology in itself is not necessarily a “green” technology. Rather, it is an enabler of green technologies, such as clean coal, renewable energies and lightweight materials and design. Given this context, our recommendations do not focus on electric vehicles or batteries themselves, but rather on the sources of the corresponding power generation and the “cleaning up” of the power sector.

#### **A. Regionalize the development and promotion of EVs in China**

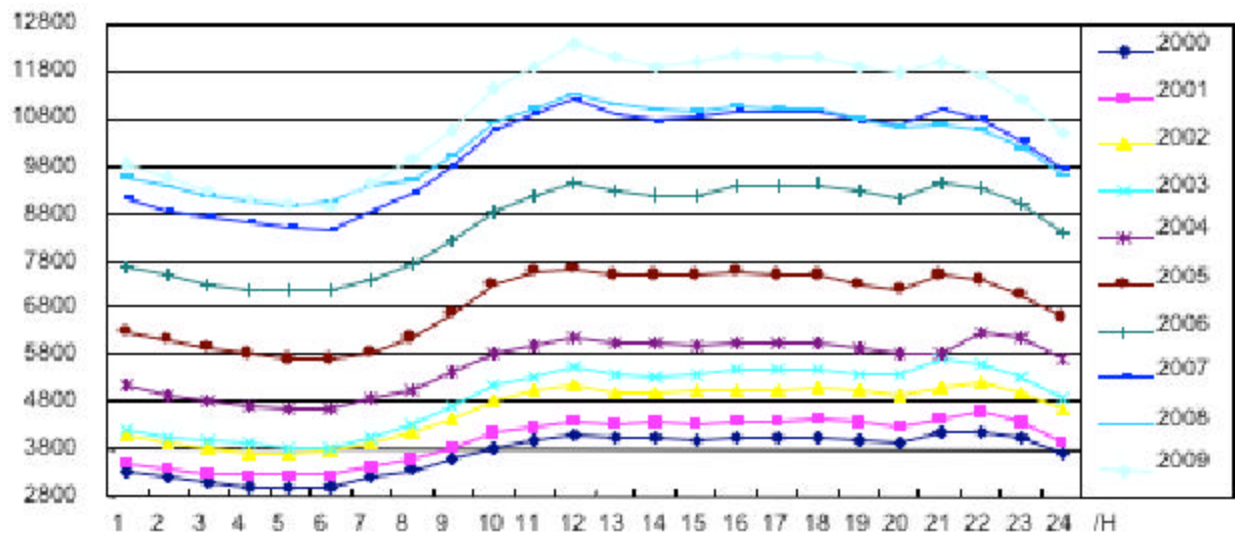
66. The comparative analysis of the seven regional power grids in China leads to an obvious conclusion: not all grids are created equal, and, thus, not all grids can deliver the environmental benefits that EV technology can enable. At least during the early stages of EV development and in the regions where electricity has higher lifecycle GHG intensity, promotion of EVs should be temporally suspended. These regions are, in particular, those served by the North China grid, and the Northeast China grid. Shenyang and Beijing should be excluded from extensive electrification at this time for this reason. Cities that would be best suited for electrification are those on the South China grid and Central China grid such as Shenzhen and Guangzhou, and to a lesser degree, those powered by the East China grid, such as Shanghai and Hangzhou.

#### **B. Optimize grid and renewable energies for transportation uses**

67. Electric vehicles are only an energy conversion technology, rather than a clean energy technology. Therefore, it is essential that the energy supply for electric vehicles be cleaned up in order to ensure the reduction of emissions of all kinds. Charging schedules and linking to renewable energies are key to this strategy. Demand for electricity is typically higher during the day than during the night. During the day people and industry are working and demand power for production as well as for air conditioning and heating use (Figure 10). Renewable energies are key to cleaning up grids across China. In order to make electric transportation truly environmentally friendly, the benefits of low carbon technology and renewable energy must be harvested. Renewable energy should be increased in areas where electric vehicles can take advantage of it.

68. If electric vehicles are charged at peak demand times, they will cause additional demand and require significant power generation capabilities to be built. The most readily available and economical electrical production is from coal at this time. In this situation electric mobility would require extra coal production and extra coal-fired power plants to be built, along with some other energy sources such as gas turbine power. However, if power is used in early morning hours when there is a reduction in other demand, then new energy supply infrastructure can be avoided. This type of coordination will definitely require smart grid technology which can either remote control charging times of vehicles, or use time-of day pricing to incent vehicle owners to charge during low load times using time-of-day pricing.

Figure 10  
Average daily summer load on the North China Power Grid (2000-2009)



Source: Shuwei Zhang. Impacts on the power sector of climate policy - Modeling with China-Second Generation Model (CSGM). Unpublished materials.

### C. Promote low-carbon version of electrification technologies, especially plug-in hybrid electric technologies

69. Plug-in Hybrid Electric Vehicles (PHEVs) usually provide higher energy efficiency and lower overall life-cycle cycle GHG emissions when compared with both the traditional internal-combustion-engine (ICE) vehicles and pure battery EVs. A PHEV extends a conventional hybrid concept to enable two “refuelling” options. Current hybrid vehicles charge or “refuel” the battery only with the fossil fuel dependent internal combustion engine. A plug-in hybrid offers the flexibility of “refuelling” directly with electricity or indirectly with fossil-fuels (gasoline or other). By definition, a PHEV describes a wide spectrum of vehicle designs that vary with the ratio of electric drive to conventional drive. At one end of the spectrum, a PHEV could refer to a mild hybrid design augmented to allow the flexibility of “plugging-in”. On the other end of the spectrum, it could refer to a dominant electric drive design such as full electric vehicle with a conventional drive “range-extender” for long journeys.

70. PHEVs take advantage of positive attributes of both ICE and battery systems, while avoiding many shortcomings associated with both powertrain technologies. PHEVs could reduce costs and weight by using much smaller battery packs and reducing the time required to charge the battery. Viewed by some as a “transitional” technology, we believe that PHEVs have potential to be a mainstream technology for decades to come.

### D. Expand fuel economy standards to include electric vehicles

71. Electric vehicles are widely expected to play a growing role in technologies for low-carbon transportation in the future. In order for consumers to be able to more objectively compare the engineering, economic and environmental performance of both, internal combustion

and electric vehicles, fuel economy standards and testing protocols need to be further improved and broadened to include all types of fuels, including electricity.

72. Further international dialogue and cooperation in this field will be essential, including the active participation of all concerned stakeholders, such as central, provincial and local governments, motor vehicle manufactures and distributors, battery producers, oil companies and electric power utilities, as well as consumer associations and consumer groups.

## Annex 1

### Case Study: Beijing City – EV in a Traffic-Constrained Megacity

Beijing is a city of more than 20 million people with the highest rate of automobile ownership amongst cities in China. Faced with intractable traffic jams, Beijing has recently applied a limit to the number of license plates that can be issued for light duty vehicles in the city every year to 240,000. Furthermore, Beijing no longer allows vehicles registered outside the city to drive on city roads during rush hours. While the city wants to promote electric vehicle use, it needs to balance technological change with traffic management.

#### Policy support

Beijing, as the capital of China, has been a strong supporter of the automotive industry. It was included in the first batch of cities in the “Ten Cities, Thousand Vehicles” program of the Ministry of Science and Technology. However, it was not identified in the *Subsidy Standards for Private Purchase of New Energy Vehicles* as a target city for the development and demonstration of personal electric vehicles. Until late 2010, the city’s main policy push has been in the demonstration of electric city buses and the construction of battery swapping stations for charging batteries. However, Beijing has proposed that by 2012, it will have introduced 23,000 electric and 7,000 hybrid cars onto the roads of the city, including 100 recharging stations and 36,000 rechargers.<sup>30</sup> The city will accomplish this task by subsidizing vehicles to the tune of RMB 3,000 per kW-h of battery capacity installed, up to RMB 60,000 for an EV or RMB 50,000 for a hybrid. The State Grid of China also plans to install battery swapping stations for private vehicles in Beijing as well, although discussions about battery standards still call this plan into question.<sup>31</sup>

Figure CS1: Swappable bus battery in Beijing



#### Industrial Support

Beijing is seeking the development of new supply chains to support government targets for on-road electric vehicles. The Beijing Automotive Industry Holding Company (BAIC) has created the Beijing New Energy Vehicle Company, (BNEV) which also brings its own lithium ion battery producer, Pride Power System Technology Co., which will provide integrated lithium battery systems. BNEV has established relationships with global suppliers including the acquisition of designs from Saab to serve as a basis for their mid-level vehicles. The company plans to offer a variety of electric vehicles to the public, producing 150,000 EVs and HEVs by 2015.

Meanwhile, bus services are developing deep value chains that can support the continuous operation of public transit with battery-powered vehicles. The Beijing Public Transport Authority (which has ordered 100 electric buses from Foton this year) has determined bus routes and operation modes. Battery supplier, CITIC Guoan Mengguli Battery Co. leased batteries based on distance traveled (in order to defray upfront costs). Beijing Institute of Technology determined charging modes, bus manufacturer Zhongtong Bus holdings determined battery form factor for fast swapping, and China Grid (and others including CNOOC) have constructed fast-swapping battery charging stations.

<sup>30</sup> Available from [http://www.china.org.cn/business/2010-11/30/content\\_21448204.htm](http://www.china.org.cn/business/2010-11/30/content_21448204.htm).

<sup>31</sup> Available from <http://english.people.com.cn/90001/90778/90860/7254247.html>.

## Annex 2

### Case Study: Shenzhen City – Policy and Industrial Trailblazer for EV in China

Shenzhen, as the home of BYD Motors, is a key leader in the development and implementation of EV production, testing, planning and infrastructure development not only in China, but around the world.

#### Policy Support

Shenzhen has been a clear policy leader in EV in China. Since recognizing its strength as a brand new and growing city, with a leading innovator in the automotive sector, Shenzhen has aimed to become the leader in electric vehicle implementation in China. As a key demonstration city in the “10 Cities, 1000 Vehicles” demonstration program of the Chinese Ministry of Science and Technology 863 Project, Shenzhen has committed to promoting 24,000 electrified vehicles by 2015.

Shenzhen City alone is targeting 24,000 electrified vehicles including:

- 3000 Hybrid-Electric buses and 1000 All-Electric “eBuses”
- 2500 All-electric Taxis (many using the BYD e65 passenger platform for e-Taxi)
- 2500 All-electric government fleet cars and incentives for 15,000 consumer EV’s

At the same time, it is aggressively promoting charging infrastructure:

- 12750 EV Battery Charging Pedestals (similar to US Level 2 chargers)
- 25 Electric Bus Fast Swapping Stations (unique to China)
- 200 Public-Access Rapid Charging Stations
- 2500 Government Fleet Charging Poles and 10000 Public-Access Charging Poles

Fig B2: 180 kW Fast Charger at BYD in Shenzhen



#### Industrial Support

Since 2003, when battery maker BYD purchased Chinese automaker Tsinchuan Automobile Company it has been a champion of innovation in the automotive sector in China. By 2006 – only three years after BYD became an auto maker, it had produced its first EV, the F3e, powered by BYD’s own lithium iron phosphate batteries. On December 15, 2008, BYD released the electric-gasoline dual mode F3DM to the Shenzhen market, and it now has around 50 of its E6 electric taxis on the road as part of a pilot project in Shenzhen,<sup>32</sup> and is aiming for 100 by mid 2011. As of September, 2009, the fleet had logged over 600,000 km of successful service in Shenzhen. This demonstration project is by far the most expansive electric vehicle use project in China, if not around the world.<sup>33</sup> The taxis can be charged at 380 V fast charging stations in 60-90 minutes. One hundred charging points with standard 220 V outlets have also been deployed around the city, and include network communications for authentication, billing and diagnostics.

One important problem facing China today in the development of electric vehicles is that nationwide standards for important components are not being produced quickly enough. In order to promote both industrial and infrastructure development, Shenzhen city has promoted its own plug standard in its large-scale demonstration project. Unfortunately, the plug standard is different than the standard promoted today by the China Automotive Technology and Research Center (CATARC).

<sup>32</sup> Available from <http://www.byd.com/company.php?index=1>

<sup>33</sup> Available from <http://www.byd.com/buzz/company-news/byd-e6-achieves-fleet-distance-milestone-over-600000-kilometers-logged/>.