

# FEATURE ARTICLE

## Reducing China's Thirst for Foreign Oil: Moving Towards a Less Oil-Dependent Road Transport System

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*China's oil demand is likely to continue increasing in the next two decades, mainly driven by its rapidly growing vehicle fleet, particularly, personal cars. Developing a less oil-dependent transport system is critical in reducing China's thirst for foreign oil and in improving air quality in the country's hazy cities. A range of policy options and strategies can be utilized to encourage cleaner vehicle technologies and fuels. Compulsory fuel economy standards are essential to push automobile manufacturers to provide efficient vehicles. Moreover, fiscal policies such as fuel economy vehicle fees and high fuel taxes could encourage Chinese consumers to purchase efficient vehicles and drive less. From the fuel supply perspective, biofuels and coal-to-liquids could help mitigate China's concern for its oil security in the interim. Most importantly, less energy and land-intensive travel options must be provided as alternatives to personal cars to meet the increasing mobility demand in China's ongoing urbanization process. Because China and the United States have high demands for imported oil and face similar risks from high oil prices, they both should take responsibility in stabilizing the international oil price. These two largest oil-consuming countries could help to enhance their energy security and control their petroleum hunger by communicating and cooperating with each other in developing and demonstrating clean and efficient vehicle technologies, substituting oil-based fuels with alternative fuels, and promoting integrated urban planning with an emphasis on maximizing overall transportation energy efficiency.*

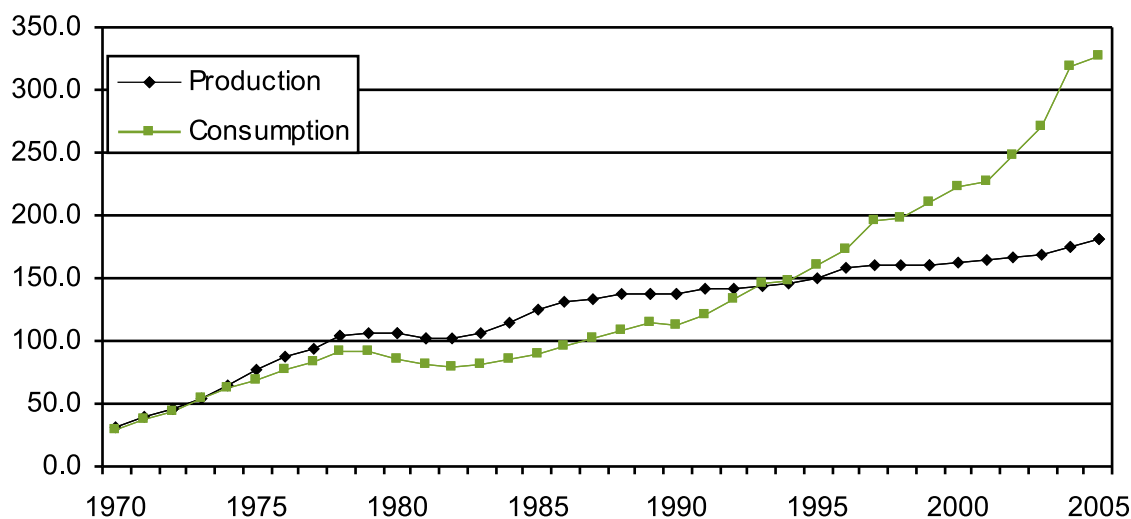
Over the past few years, significant concern has arisen over the increase in China's energy appetite and its implications for the global and U.S. energy markets ("A hungry dragon," 2004; Romero, 2004; Zweig & Bi, 2005). The attempt by China National Offshore Oil Corporation (CNOOC) to procure Unocal, the ninth largest U.S. oil company, attracted much negative attention from Congress and the news media (Kahn, 2005). CNOOC eventually withdrew its \$18.5 billion bid due to the strong objection of members of Congress. This collision brought into sharp focus the uneasy feeling in the United States towards China's growing appetite for global resources, particularly oil for energy.

China's energy consumption has increased considerably over the past twenty-five years. Its total energy consumption in 2005 was about 2.7 times more than that in 1980 (British Petroleum, 2006).<sup>1</sup> In particular, its oil consumption increased by 2.8 times over the same period, accounting for about 21 percent of total primary energy consumption

(British Petroleum, 2006).<sup>2</sup> In 2003, China overtook Japan to become the second largest oil consumer in the world, following the United States (Energy Information Administration [EIA], 2005a). Fourteen years after China became a net oil importer in 1993, its dependence on foreign oil reached 45 percent in 2005 (see Figure 1). According to the EIA (2005a), China alone accounted for one-third of global oil demand growth from 2001 to 2004. Although its total oil imports accounted only for 6.6 percent of the total global oil trade in 2004, China has borne the brunt of accusations for being the cause of soaring oil prices in the last few years ("China oil demand," 2005; Hoyos, 2004). This growing hunger for oil has been driven mainly by three factors:<sup>3</sup>

- (1) Increasing demand for personal mobility and goods transport;
- (2) The growing chemical industry that relies on petroleum products (in particular, ethane) as feedstock; and,

FIGURE 1: China's Oil Production and Consumption (1975-2005)



Source: British Petroleum (2006). *BP Statistics Review of World Energy 2006*

(3) The use of oil-fired power generators as short-term solutions to provide needed electricity on-site when there is a national or regional electricity shortage.

Among the three factors, it is estimated that increasing demand for fuel from road transport will continue to be the major force driving China's growing hunger for foreign oil. Currently, road transport accounts for one-third of China's total oil demand, and the number is likely to reach about 65 percent by 2010, if annual automobile sales grow to 8 to 9 million per year, as predicted by many experts.<sup>4</sup>

Table 1 presents projections of China's oil demand and supply. While there are significant

differences between the estimated projections, all agree that Chinese demand will continue to far outstrip the supply, and in fact domestic production will likely plateau or drop. According to the *China Energy Development Report 2003*, by the end of 2002, China had extracted 3.97 billion tons of oil, and its total remaining proven reserve was about 2.4 billion tons. Oilfields in the eastern region, such as Daqing and Shengli have been exploited for decades and their production has plateaued, or has been decreasing. Although output from oilfields in western China and offshore are gradually picking up, these increases are unlikely to offset the production decline of mature oilfields in eastern China.

TABLE 1: China Oil Demand and Supply Projections (Million Tons Per Year)

	2010	2015	2020	2025	2030
<b>Demand Projections</b>					
IEA (2004)	375		503		636
EIA (2006a)	450	540	660	780	920
China Energy Development Report (2003)	310	350	400		
<b>Supply Projections</b>					
IEA (2004)	168		137		112
EIA (2006a)	172	167	162	162	167
China Energy Development Report (2003)	170-190	180-200	170-190		

Note: IEA source is *World Energy Outlook 2004* (reference scenario, China's annual oil demand grows 3.6% from 2002 to 2030); EIA source is *International Energy Outlook 2006* (reference scenario, China's oil demand grows 4.5% annually on average from 2003 to 2025).

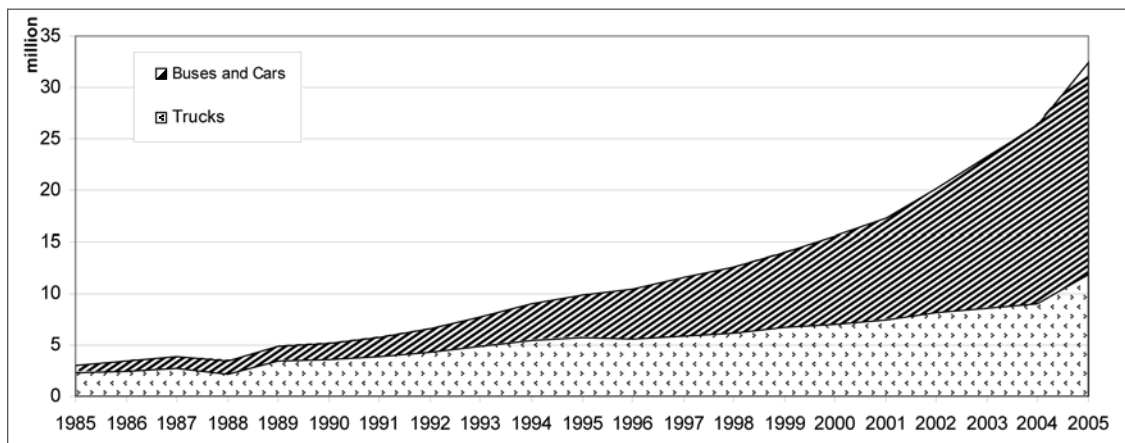
This scenario has resulted in unease not just within China, but also among major global oil importers, particularly the United States and Japan. To a significant extent, China's foreign policy in recent years has been influenced by its need for foreign oil (Downs, 2004; Lieberthal & Herberg, 2006). With a strong preference for energy self-reliance, China's leaders are concerned about the uncertainties of price and availability related to acquiring hundreds of millions of tons of oil from world markets. International oil supply can be interrupted by political instability of major oil supplying countries, and major natural disasters like Hurricane Katrina. What makes the Chinese leaders even more uncomfortable is the country's heavy reliance on foreign vessels to transport its oil from the Middle East (45 percent of China's imported oil in 2004) and Africa (29 percent in 2004). China notably lacks naval capacity to protect oil cargo on the high seas and to patrol the Strait of Malacca, through which four-fifths of its oil imports pass (Jaffe & Medlock III, 2005; Lieberthal & Herberg, 2006; Berger, 2005). Meanwhile, soaring oil prices bring additional costs to China's economy and likely make its manufactured goods less competitive. In addition, Chinese international relations experts commonly anticipate

a possible oil embargo by the United States and its allies, if China enters a severe confrontation with them (Cao, 2005; Zha, 2005; Zweig & Bi, 2005).

Because oil is such a critical energy source, China (like many other countries) has devoted considerable efforts to address its oil security. China's diverse strategy to promote oil security include: (1) diversifying international sources of supply; (2) reducing total imports by improving energy efficiency; (3) boosting domestic supply and substitute fuels; (4) building up a strategic oil reserve (not in existence yet); and (5) establishing cooperative relations with major oil importing and producing countries.

Growing media attention on China's expanding oil search often focuses on the threat it poses to global oil markets. In contrast, this paper discusses domestic steps that China could take in the transportation sector to reduce its dependence on foreign oil. The remainder of this paper compares international and Chinese practices in addressing the conflicts between increasing transportation needs and issues such as oil security, congestion, and urban air quality. The paper concludes with a discussion on possible areas of cooperation between China and the United States to address their respective oil dependence.

**FIGURE 2: Registered Vehicle Population in China (1985-2005)**



Note: In the Chinese statistics, buses and personal vehicles are lumped together counted as passenger vehicles.  
Source: China Automotive Technology and Research Center (2006a, 2006b).

### ENERGY DEMAND BY CHINA'S GROWING VEHICLE FLEET

Until a couple of decades ago, foreigners visiting China were impressed by the sea of bicycles in cities. Gradually, bicycles have given way to a wide

array of vehicles. Studies of trip shares taken by residents in Shanghai, Wuhan, and Xi'an show a rising (although still small) share of private vehicles for trips, and falling trends for non-motorized modes (Schipper & Ng, 2004).<sup>5</sup>

The Chinese leadership determined in the early 1990s to promote the automobile industry as a “pillar” industry in order to propel the country’s economic growth. Realizing China’s lack of indigenous automobile technical capacity, central decision-makers opened the sector to international investment and welcomed foreign automakers to form joint-ventures with Chinese auto companies (Gallagher, 2003). At the same time, China’s growing economy was demanding more transportation services for both goods and people, and a rising middle class has led to growing demand for personal vehicles. Consequently, the vehicle population in China has shot up dramatically, especially after the mid-1990s. (See Figure 2). China’s total vehicle population amounted to about 33 million at the end of 2005, its level of motorization is extremely low in comparison to industrialized countries (China Automotive, 2006a, 2006b).<sup>6</sup> In 2005, there were about 25 vehicles per thousand people in China; in contrast, the corresponding number was about 800 in the United States, 580 in Japan, and 300 in South Korea.

A joint report by the China Academy of Engineering and the U.S. National Research Council (2003)—*Personal Cars and China*—developed three scenarios for China’s future vehicle population. The study assumes that China’s vehicle fleet will grow at the same pace as its national economy in the next two decades. It predicts that by 2020, China’s total vehicle population will reach 80 or 110 million if its annual economic growth is 8 or 10 percent, respectively.<sup>7</sup> Notably, actual vehicle sales in China have grown much faster than the increase in its national income in the past few years. There were almost 6 million more vehicles in use in China than the anticipated number under the joint study’s high-growth scenario for 2005.

Among the three categories of motor vehicles (trucks, buses, and cars), sales of cars have grown most rapidly. Trucks used to dominate the vehicle market until 2002, when total sales of cars surpassed that of trucks, reaching 1.13 million. 2002 and 2003 witnessed 57 and 77 percent boost in car sales. The share of cars in total vehicle sales reached nearly 70

## BOX 1. Safety and Environmental Ramifications of the Growing Vehicle Population in China

Traffic safety has become a major concern accompanying vehicle population growth in China. Road accidents reported to the communications and public security bureaus almost tripled from 1991 to 2002. The number of reported accidents hit historical high of nearly 800,000 in 2002. According to the *Automotive Industry of China 2005*, the annual number of traffic fatalities almost doubled during the same period, from 53,000 to 100,000. In 2004, the total number of deaths due to traffic accidents in China was just under 80,000, almost twice as much as those in the United States.<sup>1</sup>

Besides the cost of accidents, the growing vehicle population has become a major contributor to urban air pollution, particularly in China’s four megacities—Beijing, Shanghai, Guangzhou, and Shenzhen, which together account for about 20 percent of the country’s total fleet. Beijing alone has about one-eighth of China’s vehicles (2.7 million vehicles were registered in Beijing as of spring 2006 and over 1,000 new vehicles are added to Beijing’s fleet each day). In the late 1990s, vehicle emissions in Beijing contributed to 46, 78, and 83 percent of total NO<sub>x</sub>, HC, and CO emissions, respectively, as well as 68 percent of ambient NO<sub>x</sub> and 77 percent of CO concentrations (Fu, 2000; Hao, 2001). Vehicle emissions are also a significant source of airborne particulates (PM<sub>10</sub>, particles with aerodynamic diameter no more than 10 microns), especially fine particles (PM<sub>2.5</sub>, particles with diameter less than 2.5 microns), which can deposit deeply in lungs and causes serious health effects, such as asthmas attacks, worsening lung diseases, and heart damage. Annual PM<sub>10</sub> concentration in Beijing was 50 percent higher than the Chinese standard (which is only half as strict as the U.S. current standard, which permits only 50 micrograms per cubic meter of air (ug/m<sup>3</sup>)—a standard the U.S. EPA has been pushing to significantly tighten). Although PM<sub>2.5</sub> is more detrimental to human health, China has not yet established standards for ambient PM<sub>2.5</sub> concentrations. In addition, ground-level ozone concentrations in Beijing are frequently higher than the Chinese national standard; 67 days and 285 hours of ozone concentration violations were recorded by Beijing EPB in the summer and fall of 2004.

### NOTE

1. <http://www-fars.nhtsa.dot.gov/main.cfm>

percent in 2005, and it is likely to continue rising in the near future (China Automotive, 2006a, 2006b).

There is no doubt that increased motorization is bringing significant benefits to Chinese society, such as economic growth resulting from the burgeoning auto industry, enhanced exchange and flow of labor and goods, and improved social welfare and personal freedom from increased mobility. However, increased motorization has tremendous ramifications for energy demand and security, infrastructure capacity, urban traffic management, environmental impacts, and traffic safety. (See Box 1).

It is very difficult to accurately estimate future oil demand for transportation in an emerging economy like China. Oil demand by road transport depends on the size of vehicle population, average mileage driven per year, and the fleet fuel efficiency. All three variables depend on various other factors, such as China's economy, fleet composition, infrastructure capacity, availability of alternative travel modes, and policies on energy, environment, and transportation. Despite uncertainties related to these factors, much can be done to reduce China's oil demand from road transport. The next section examines Chinese fuel economy standards and adoption of technologies that can improve fuel economy.

## STANDARDS AND TECHNOLOGIES FOR BETTER FUEL ECONOMY

Experts have looked at the potential effects of a more efficient fleet on Chinese oil consumption. For example, He et al. (2005) assumed three different scenarios for the Chinese fleet fuel economy from 2002 to 2030:

(1) *No improvement.* New vehicles maintain the same fuel economy as the average during the 1997-2002 period;

(2) *Moderate improvement.* New vehicles are required to improve their fuel efficiency by 20 percent by 2008 and an additional 20 percent by 2018; and,

(3) *High improvement.* New vehicles are required to improve their fuel efficiency by 30 percent by 2007 and an additional 40 percent by 2017.

He (2005) concluded that if China adopts the stringent vehicle fuel economy requirements under the high improvement scenario, the total oil demand by road transport in China would be about 40 million tons less than the no improvement scenario

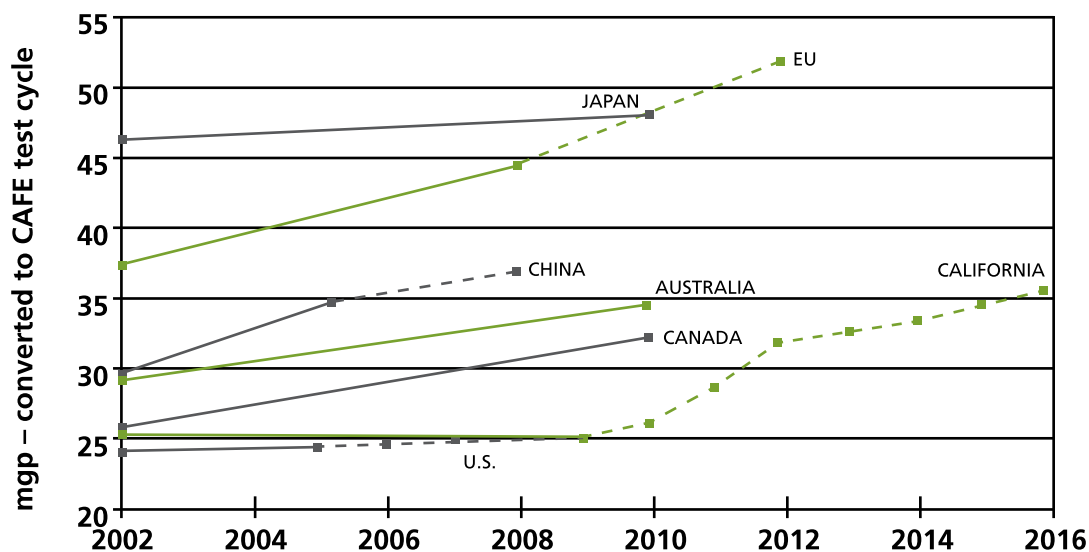
by 2020, and about 90 million tons less by 2030.<sup>8</sup> Reaching these goals remains challenging considering the current low level of fuel efficiency in China and obstacles to strong standards or fiscal policies to push such a technology switch.

### Fuel Efficiency Standards

The fuel efficiency of most Chinese in-use vehicles is worse than that of comparable ones in the industrialized countries (China Academy of Engineering & National Research Council, 2003). To encourage foreign companies to bring fuel-efficient technologies to the Chinese market, the central government issued fuel efficiency standards in October 2004; the standards are applicable to cars, SUVs, and multi-purpose vans weighing less than 3,500 kg (7,700 pounds). Following the Japanese model, Chinese fuel efficiency requirements vary according to vehicle weight category and transmission type. In contrast to the U.S. Corporate Average Fuel Economy (CAFE) standard, which is based on fleet average, the Chinese standards require each individual vehicle model to meet the standard for its weight class. To discourage automobile manufacturers from producing inefficient heavy passenger vehicles, the standards for heavier weight classes (>2,110 kg) are relatively more stringent than those for lighter weight classes.<sup>9</sup> China's new standards are to be implemented in two phases: new vehicle models were required to meet their respective Phase I standards by 1 July 2005, and Phase II standards by 1 January 2008.<sup>10</sup> For the same weight class vehicles, Phase II standards are about 10 to 13 percent stricter than Phase I standards.

An and Saucer (2004) compared fuel economy standards of selected countries (see Figure 3), which showed that the average fuel economy of light-duty vehicles (LDV) sold in China in 2002 was about 29.4 miles per gallon (mpg)—better than that of LDVs sold in both the United States (24.1 mpg) and Canada (25.6 mpg). This is because most passenger vehicles sold in China have much smaller engines and weigh less than those sold in North America. Even with the Phase II fuel economy standards, the fleet fuel economy of new LDVs in China will still be far behind the EU (37.2 mpg) and Japan (46.3 mpg) in the next ten years. To catch up with Europe and Japan, China will need to tighten its fuel economy standards further and push automobile manufacturers to employ advanced technologies on vehicles sold in the Chinese market.

FIGURE 3: Comparison of Fuel Economy Standards across Countries



Note: Dotted lines represent proposed standards. Only passenger vehicles are included in the comparison.  
Source: An and Sauer (2004).

### New Technologies

Many countries have taken actions in developing and deploying advanced vehicle technologies that can lead to better fuel economy; helping to meet the challenges of increasing fuel prices, national energy security, and environmental impacts associated with vehicle use. The adoption of such technologies has resulted in substantial improvement of fuel economy in most OECD countries, especially in the early-to-mid 1980s.<sup>11</sup> Since the mid-1990s, commitments to reduce greenhouse gas emissions led to wide adoption of advanced fuel-efficient vehicle technologies in Europe and Japan, but not much in North America and Australia. Table 2 summarizes various technologies (grouped into seven categories) that can improve fuel economy.

Most vehicles produced in China are based on models initially sold in industrial countries. Before the mid-1990s, only a handful of vehicle models were produced in China, and the employed technologies were about ten years behind those in Europe and the United States. Since the late 1990s, lured by the rapidly growing Chinese automobile market, major international vehicle manufacturers established joint ventures to produce their brands in China. The intensified competition provoked these manufacturers to bring in more contemporary models. Common technologies for fuel efficiency adopted

in these countries (e.g., technologies related to drag and rolling resistance reduction and computer-controlled electronic spark ignition and transmission) and those for emissions control (e.g., three-way catalytic converters) are widely employed on vehicles produced in China. However, more advanced engine and transmission technologies for greater fuel efficiency, which are still in the early adoption process in the west, (such as cylinder cut-out, gasoline direct injection, and continuously variable transmissions) have rarely been brought to China because of their high costs. It seems the fuel efficiency standard of most automobile models that international companies bring to produce in China is comparable to that of their equivalent foreign models (Gallagher, 2005; Bradsher, 2006). Nevertheless, models developed by Chinese automakers themselves still consume 10 to 30 percent more energy than those made by foreign technologies and design (Gan, 2003).

### Hybrid Systems

As shown in Table 2, significant fuel economy gains can be obtained through hybrid technologies, and a full hybrid system can lead to a 30 to 50 percent increase in fuel efficiency.<sup>12</sup> Following Toyota and Honda, two U.S. companies—Ford and GM—have also applied hybrid technologies to some of their models. As of mid-2006, 6 car, 5

TABLE 2: Technologies for Improving Vehicle Fuel Efficiency

<i>Approach to improve fuel efficiency</i>	<i>Technology</i>	<i>Tested fuel efficiency benefit (%)</i>
Reducing tractive force requirement	Weight reduction (5-10%)	3.5 to 7
	Drag reduction (10-20%)	2 to 4
	Rolling resistance	2 to 4
Improving engine efficiency	Engine downsizing & increase specific output	1 to 2
	Variable valve timing	1.5 to 2.5
	Variable valve lift and timing	5 to 7
	Cylinder cut-out	6 to 8
	DI diesel engines	35 to 40
	Gasoline direct injection	12 to 15
	Electronic fuel injection	1 to 2
Improving transmission efficiency	6-/5- speed automatic	2.5 to 5
	Continuously variable transmission	5 to 7
	Electronic transmission control	1 to 2
Hybrid technology	Mild-hybrid (42 V)	5 to 7
	Full hybrid	30 to 50
Reducing internal frictions	Engine friction reduction	2 to 4
	Fuel efficient lubricant (5W-20 oil)	0.5 to 1
Reducing power consumption by accessories		0.5-2.5
Fuel-saving driver support devices		10-20

Source: European Conference of Ministers of Transport and International Energy Agency (2005).

SUV and 2 pick-up truck models in the U.S. market are equipped with hybrid technologies. In contrast, the only hybrid automobile model available in China is Toyota's Prius. To demonstrate its intention to bring its best technologies to China, Toyota decided to produce 3,000 Prius cars each year for the Chinese market at its joint venture with the First Auto Works in Changchun. The Prius cars assembled in China are priced between 288,000 and 302,000 Yuan (\$36,000 and \$37,750)—considerably higher than what ordinary Chinese consumers can afford. In hopes of developing domestic hybrid vehicles, the Ministry of Science and Technology (MoST) organized major Chinese automakers to conduct R&D on hybrid technologies. As of mid-2006, Chinese automakers and research institutes have made more advances in hybrid buses than hybrid cars. For instance, six prototype hybrid buses developed by Dongfeng Motor Corporation have been in service around Wuhan since 2002; and the company plans to commercialize its hybrid bus production in the near future.

#### *Advanced Diesel Engines*

Using an advanced diesel engine instead of a regular gasoline engine can improve fuel efficiency by 35 to 40 percent. (See Table 2). European automobile manufacturers are in the lead in terms of applying advanced diesel engines to passenger vehicles. Sales

of diesel cars accounted for about 50 percent of all passenger vehicle sales in Western Europe in 2005. In comparison, almost all the cars sold in China run on gasoline (99 percent in 2005). China's central decision-makers have not yet decided whether the country should follow the European path to dieselize cars to improve fleet fuel efficiency. The hesitation results from the higher production costs of diesel engines, the low quality of Chinese diesel, and the difficulty of diesel vehicles to meet future stricter emission standards.<sup>13</sup> The majority of new heavy-duty vehicles (i.e., trucks and buses) made in China have been dieselized. Despite this, Chinese-made heavy trucks on average are still about 20 percent less efficient than comparable models produced in industrialized countries (China Automotive, 2005). Moreover, there are no fuel efficiency standards for heavy duty vehicles.

#### *R&D Expenditure*

Low technology development in Chinese-produced cars stems from the paltry R&D expenditure of China's domestic automobile industry—about 1.3 percent (about \$13 million) of its total turnover was spent on R&D in 2003, which is considerably less than the R&D expenditure of automobile companies in industrialized countries (on average about 5 percent of revenues) (Safford & Prasad, 1999). Japanese automobile companies lead in R&D

spending: in the late 1990s, Toyota and Nissan spent about 6.3 and 9.3 percent of their revenues on R&D, respectively. Indeed, R&D expenditure in the motor vehicle industry accounts for a very large share of manufacturing expenditure in the EU, the United States, and Japan.<sup>14</sup>

#### *Technology-Pushing Regulations*

Analysis of historical trends in fuel economy in OECD countries shows that when regulations and policies to improve fuel economy are absent, efficiency-related advances have frequently been used to improve vehicle performance, instead of reducing fuel consumption (Zachariadis, 2006). The fuel economy of the U.S. fleet has been stagnant since the mid-1990s, although fuel-efficient technologies have improved. Such technologies are often used to accommodate increased vehicle weight and to improve performance such as total horsepower and time to reach 60 miles per hour from a stop (U.S. Environmental Protection Agency, 2005). In contrast, during the last decade, high fuel taxes and the voluntary agreement of auto manufacturers to reduce CO<sub>2</sub> emissions in Europe and Japan have led to continual improvements in fleet fuel efficiency. The divergent paths taken by the United States, the EU countries, and Japan demonstrate the importance of deliberate government policies and actions in directing automakers' R&D efforts, influencing vehicle fuel efficiency and car use, and ultimately affecting transport fuel consumption per capita.<sup>15</sup> The next section presents a discussion of fiscal policies in industrialized nations that China could potentially adopt to reduce energy consumption by encouraging the purchase of efficient vehicles and restraining personal vehicle ownership and use.

### **FISCAL POLICIES FOR PROMOTING EFFICIENT VEHICLES AND VEHICLE USE**

International experience demonstrates that well-designed fiscal policies can promote cleaner and more efficient road transport by influencing people's decisions on vehicle ownership, as well as the duration, volume, and characteristics of vehicle use.

#### **Policies Influencing Ownership**

Singapore provides an extreme example of the extent to which a country can restrict the growth of vehicle ownership through prohibitive fees and taxes. With high entitlement and registration fees and tariffs in

Singapore, owning an Audi A4 1.8L is estimated to cost about \$182,000, which is almost five times its sticker price in the United States (ExpatSingapore, 2005).<sup>16</sup> Consequently, Singapore has successfully controlled its vehicle population growth at 3 percent per year since 1990, in contrast to a 7 percent increase in the late 1980s (Singapore Vehicle, 1999).

Many OECD countries do not restrict ownership but have attempted to influence consumers' decisions on what kind of vehicles to purchase by offering incentives such as tax/fee reductions and rebates for clean and efficient vehicles. For instance, the Japanese government provides a hefty (25 to 75 percent) acquisition tax reduction for low-emission vehicles, and also provides direct subsidies for purchasing alternative fuel vehicles. Similarly, Denmark offers a 16.7 percent acquisition tax reduction for gasoline cars with a fuel economy between 60 to 95 mpg, a 67 percent tax reduction for gasoline cars with a fuel economy over 95 mpg, and for diesel cars with a fuel economy over 105 mpg. Germany offers up to \$1,900 (for gasoline cars) or \$2,600 (for diesel cars) exemption of circulation tax if these cars can meet Euro IV emission standards and emit less than 90g of CO<sub>2</sub> per km (equivalent to fuel economy of 60 mpg) (Gordon, 2005). In the United States, buyers of hybrid vehicles can enjoy up to \$3,400 in tax credit, while gas-guzzling cars that get less than 22.5 mpg are subjected to a progressive tax.<sup>17</sup>

#### **Policies for In-use Costs**

The amount of vehicle use (average mileage driven per year per vehicle) directly influences fuel consumption and emissions. Thus, fiscal policies influencing the total mileage driven, such as fuel and other in-use costs, are more effective than ownership-oriented policies in restraining fuel use and controlling environmental damages by road transport. Overall, the EU countries, by comparison to international standards, have high taxes on fuels. In 2003, fuel taxes accounted for about three-quarters of gasoline retail prices in western European countries, while they comprise only about one-quarter of the gasoline (premium) price in the United States (Gordon, 2005). The percentage has dropped to 60 percent in West Europe and 12 percent in the United States in 2006 due to soaring crude oil prices. Still, gasoline taxes charged in most western European countries are more than ten times higher than those in the United States (\$3.8-4.4 per gallon versus \$0.4 per gallon)(EIA, 2006b). High fuel costs have made Europeans



more frugal than Americans when it comes to driving a car.

The current excise tax on vehicle fuels in China is about 10 cents per gallon. China's fuel taxes are probably lower than in the United States, given that the regulated gasoline price in China (which rose to \$2.5 per gallon only in March 2006) has been lower than the average gasoline price in the United States.<sup>18</sup> If China continues its low fuel price policy, its level of vehicle fuels consumption is likely to follow the U.S. path. Such a path is definitely not sustainable for either China or the world.

### China's Fiscal Policies for Autos

At present, there are nine types of taxes and fees pertaining to vehicle purchasing, registration, and utilization in China. These taxes and fees include: value added tax (17 percent); excise tax (3 to 20 percent, depending on engine size);<sup>19</sup> vehicle purchasing tax (10 percent); tariff (25 percent);<sup>20</sup> registration fee (about 200 Yuan); road maintenance fees (1,320 Yuan per year for a passenger vehicle); and tolls (China Automotive Technology and Research Center, 2005). Most of these national fiscal policies intend to generate revenue instead of influence vehicle ownership and use. Thus, vehicle ownership is not restrained nationwide except in Shanghai, where the municipal government issues only about 60,000 new vehicle licenses each year, due to its concern for urban congestion and air quality.<sup>21</sup> Tolls are commonly collected for highway use in China. Like in most countries, they are designed to recover the costs associated with highway construction and maintenance, not to discourage or moderate vehicle use. The only fiscal policy the central government has employed to promote clean and fuel efficient vehicles is the excise tax.

#### *Excise Taxes*

In order to encourage automobile manufacturers to produce vehicles with fewer emissions than existing standards, the Chinese government has offered a reduced excise tax for purchasing relatively clean vehicles. Currently, new light duty vehicles (LDVs) in compliance with the national 2007 emission standards enjoy a 30 percent reduction of the excise tax. Emission limits in the Chinese 2007 standards are equivalent to those in Euro III standards, which were effective in the EU from 2000 to 2004.

A new automobile excise tax scheme took effect in China in April 2006 in an effort to discourage the purchase of passenger vehicles with large engines.

The rates of the previous automobile excise taxes ranged between 3 and 8 percent (depending on engine size). When China's central financial agency established the previous tax rates in the early 1990s, the consumption tax rates for SUVs were low (3 or 5 percent), for they were considered to be off-road vehicles and mainly used in the countryside where the economy was less developed (Huang, 2005). Seeing that the high popularity of SUVs and pickup trucks among ordinary U.S. consumers had led to low fleet fuel economy in the United States, the Chinese leadership has been determined to avoid the same trend in China, and decided to impose steep excise taxes on cars and SUVs with large engines. The new excise tax scheme classifies LDVs into six groups based on their engine size.<sup>22</sup>

The new tax scheme makes cars with engines smaller than 1.5 liters, which are popular among ordinary Chinese consumers (accounting for about 20 percent of market share in 2005), more appealing due to their low prices. However, the new tax does not have direct impact on the costs of cars with an engine size between 1.5 and 2.0 liters, which contribute to about half of LDV sales in China. Nevertheless, it did push the prices of SUVs and large cars much higher. The excise taxes for cars with an engine size between 2.5 and 3.0 liters increased by 4 percent, and those with engine size between 3.0 and 4.0 liters, by 7 percent. However in China, companies or government agencies are the main buyers of these larger cars—such consumer groups are not sensitive to moderate price increases. Luxury LDVs with very large engines felt the tax impact the most. For example, the price of Toyota's Land Cruiser (4.7 liters, 8 cylinders) in the Chinese market increased by about 18 percent (from about \$90,000 to \$106,000); that of a BMW 750i increased by 13 percent (from about \$168,000 to \$191,000). The long-term oil-saving effects of the high excise taxes on luxury vehicles are yet to be seen, since the sales volume of these vehicles are rather small in China.

#### *Fuel Taxes*

Compared to Western countries, refined vehicle fuels are more regulated in China and sold at a relatively cheap price domestically. In summer 2006, gasoline (regular) sold in China was priced around 5 Yuan per liter (\$2.5 per gallon), which was about 17 percent below the average gasoline price in the United States (\$3.0 per gallon), and merely 40 percent of that in Western Europe (\$7 in the Netherlands and

\$6.2 in France) (EIA, 2006b). Because the Chinese central government has worried that high fuel prices will cause rapid inflation and lead to social turmoil, it has intentionally kept taxes on fuels very low.

Since the mid-1990s, the Chinese central financial agencies have been pondering a plan to replace road maintenance fees with a fuel tax so that the charge will be linked to the amount of driving (LDV owners in China must pay about \$165 for road maintenance fees per vehicle each year). However, to date, a fuel tax has yet to be adopted, except for a trial implementation on the island of Hainan Province initiated in 1994.<sup>23</sup> Top officials at China's Ministry of Finance (MoF) publicly announced at the end of 2005 that they anticipate the imposition of a fuel tax before 2010. Nevertheless, before the central government can impose the long-awaited fuel tax, it will have to find ways to address four major barriers (Jia, 2005; Liu, 2005; Xu, 2004; Zhang & Ming, 2005):

(1) *Inflation fears.* There is concern that a fuel tax could spur nationwide inflation; the central government believes the impacts of a fuel tax on China's economy will be less severe when the international oil price drops below \$35 per barrel. This strategy is somewhat ironic since imposing the tax when oil price is high is more likely to make consumers modify their behavior.

(2) *Bureaucratic disputes over tax use.* Road maintenance fees and tolls are currently collected and managed by the Ministry of Transportation (MoT) and their corresponding agencies at local levels; and the revenues are used for road construction and maintenance. In contrast, fuel taxes would be collected by tax bureaus and managed by MoF. These agencies have not reached an agreement on how MoF and MoT would jointly administer the expenditure of road construction and maintenance if China adopts larger fuel taxes while abandoning road maintenance fees and lowering tolls.

(3) *Concerns of overburdening the rural poor.* Chinese policymakers generally believe that fuels used by off-road vehicles, especially agricultural vehicles, should be exempted from taxation. Therefore, to make sure that farmers and other economically disadvantaged vehicle users will not be worse off under a fuel tax, an effective yet easy-to-implement reimbursement plan needs to be developed.

(4) *Disagreement on where to collect the tax.* The debate on whether the tax should be imposed at the pump or at the refinery gate remains undecided. Only 30 percent of transport fuel is purchased at the pump

in China, so it would appear reasonable to collect the tax at the refinery gate. However, large and politically influential state-owned refineries argue that since small, private refineries frequently evade taxes, a fuel tax at the refinery gate would only increase the costs for large refineries, making it even more difficult for them to compete with private ones.

## ALTERNATIVE FUELS FOR ROAD TRANSPORT

### LPG and CNG Programs

To address vehicle emissions issues and mitigate oil security pressure, the Ministry of Science and Technology (MoST) initiated a "National Clean Vehicle Action Program," which prioritized the research, development, and demonstration projects of alternative fuel vehicles.<sup>24</sup> It gave special emphasis to vehicles using liquefied petroleum gas (LPG) and compressed natural gas (CNG). MoST chose nineteen cities and provinces, including Beijing, Shanghai, Tianjin, and Chongqing, to demonstrate LPG and CNG vehicle technologies. As of the end of 2004, these nineteen locales had added 215,000 LPG or CNG vehicles to their bus and taxi fleets and built 712 refueling stations. About half of the buses and taxis in these areas can run on LPG or CNG (China Automotive Technology, 2006). However, some problems have emerged during the program implementation: (1) there are not enough LPG/CNG refueling stations, so many retrofitted vehicles continue running on gasoline; (2) the technologies employed to convert gasoline vehicles to dual-fuel vehicles are often primitive; and (3) the conversion does not always lead to fewer emissions (Zhao & Gallagher, 2003).<sup>25</sup>

China is likely to continue expanding its use of LPG and natural gas for transportation. Nevertheless, due to limited domestic LPG and natural gas reserves, and because other sectors compete for these two resources (residential use and power generation), LPG and natural gas are likely to remain a minor portion of the total energy used in the Chinese transportation sector.<sup>26</sup> Switching bus and taxi fleets from using gasoline to LPG or natural gas is unlikely to relieve China's energy security concern, but it could be beneficial to urban air quality if proper technologies are employed.

### Ethanol Pilots

Using domestically available renewable fuels to substitute fossil fuels is an appealing concept to many

oil importing countries. Brazil has been the most successful in achieving this goal.<sup>27</sup> In China, pilot projects using the mixture of gasoline and ethanol (10 percent ethanol, E10) first started in five cities in Henan and Heilongjiang provinces in 2002. Encouraged by the successful promotion of E10 in the five cities, the National Development and Reform Commission soon designated nine provinces to promote E10.<sup>28</sup> Some of the provinces, such as Anhui, Henan and Jilin, now only allow E10 to be sold at the pump. Four state-owned companies were chosen by the Chinese central government to produce ethanol for E10; MoF and the State Administration of Taxation have offered significant subsidies and the exemption of VAT (17 percent) and excise tax (5 percent) to guarantee the financial viability of these companies.<sup>29</sup> These companies produced about 2 million tons of ethanol in 2005, using excess corn and wheat as feedstock.

However, the potential of corn ethanol replacing petroleum fuel is limited, due to the following reasons: (1) the net energy balance of corn ethanol is rather small (at best, energy output from corn ethanol is only about 25 to 40 percent higher than the energy input required to produce it);<sup>30</sup> (2) subsidizing a large ethanol industry would be a heavy burden on central coffers; and (3) China needs to use its limited cultivatable land to feed its huge population. Cellulosic ethanol, which can be produced from low-value plant materials such as corn stalks, sawdust, or switchgrass, has a better potential than corn ethanol as a domestic renewable substitute for gasoline in the long run, due to its lower fuel-cycle energy input, long-term low production cost, and lower CO<sub>2</sub> emissions (Hammerschlag, 2006; Worldwatch Institute, 2006). Nevertheless, the technology is not commercially available yet internationally. The United States has paid much attention to cellulosic ethanol in recent years. In his 2006 State of the Union address, President Bush pledged to make cellulosic ethanol, “practical and competitive within six years.” The U.S. Department of Energy (2006) issued a roadmap for developing and deploying technologies that will lead to large-scale, low-cost cellulosic ethanol production. Given their common interest in this biofuel, the United States and China could collaborate on developing and demonstrating cellulosic ethanol technologies.

### Coal-to-Liquid Fuels

Another technological solution that MoST started pursuing is coal-to-liquid (CTL) fuels. High crude

oil prices in recent years have raised the aspiration of Chinese coal companies to build CTL facilities. Chinese experts estimate that CTL can be profitable in China as long as the international oil price stays above \$28 per barrel (Xu, 2005a). Shenhua, the largest coal corporation in China, is constructing a direct liquefaction plant in Inner Mongolia. The first phase of the plant is scheduled to finish in 2007 with an annual production capacity of 3.2 million tons; the second phase of the plant will add another 1.8 million tons of annual capacity. In July 2005, Shell and Shenhua signed an agreement to study the feasibility of building a joint, indirect liquefaction CTL plant (with a capacity of 3 million tons per year) in Ningxia. Shenhua aims to raise its CTL capacity to 30 million tons by 2020 (Xu, 2005b). The central government hopes China will be able to produce about 35 million tons of transport fuels from coal by 2020, which could supply 5 to 10 percent of total road transport energy demand. This ambitious goal demands a significant amount of capital investment—at least \$50 billion would be needed—and implies tremendous financial risks (Wang, Li, & Cong, 2005).<sup>31</sup>

From the environmental perspective, if appropriate processes are employed, liquid fuels converted from coal for transport can be ultra-clean (i.e., no residue, no metal) with extremely low levels of aromatics and sulfur. When combined with advanced engine and treatment technologies, such fuels can help to reduce vehicle emissions such as NO<sub>x</sub> and PM significantly. However, the coal liquefaction process consumes a considerable amount of energy. Therefore, if the deployment of CTL technology is not coupled with carbon capture and sequestration, the CTL process will lead to more CO<sub>2</sub> emissions (100+ percent) than the oil refining.

### Methanol

China’s abundant coal resources also inspired Chinese policymakers to explore the potential of methanol from coal as an alternative to conventional motor fuels. Shanxi Province carried out an experiment on vehicles using a mixture of 15 percent methanol and 85 percent gasoline (M15). Four Shanxi cities started supplying M15 at the pump in addition to regular gasoline in 2002; and three of them became M15-only cities by October 2005. Chery, a domestic automaker, signed an agreement with the provincial government to develop and deliver 620 pure-methanol cars in 2006. In addition, the province also plans to retrofit 600 existing

taxis into pure-methanol cars. The provincial government in Shanxi hopes to expand its methanol production capacity to 10 million tons by 2010.

## LESS ENERGY INTENSIVE TRAVEL MODES

Approaches such as improved vehicle technologies and expansion of road systems cannot solve all air pollution, oil consumption, and traffic congestion problems associated with a growing vehicle fleet. A paradigm shift in transportation planning and land use is essential to address these problems adequately. Urban transportation and energy use need to be thought of in terms of a combination of land use and infrastructure patterns that either favor car use, or favor public transport and non-motorized travel modes (Newman & Kenworthy, 1999).

Congestion can cause low vehicle fuel economy and high emissions, due to more time spent idling. The Texas Transportation Institute studies congestion in 85 urban areas throughout the United States each year. It estimates that a total of 2.23 billion gallons of fuel was wasted in 2003 throughout these urban areas due to congestion—about 7.1 million tons of oil equivalent (Schrank & Lomax, 2005).

Many cities in China have started experiencing sluggish traffic flow despite a massive expansion of urban expressways and artery roads. In 2004, the vehicle population in Shanghai increased by 15 percent, and total road length increased by about 19 percent. However, the average traffic speed on urban expressways slowed down by 17 percent. In Shanghai, the average speed on artery roads is less than 13 miles/hour and even lower during peak hours (Shanghai City, 2005). Despite Shanghai's spectacular eight-lane ring roads, the average speed of city driving was not much better in Beijing—about 10 miles/hour (Liu et al., 2005).

Booming urbanization in China is complicating transport challenges. In 1978, less than 18 percent of China's 963 million people were living in 223 urban areas, among which, only 15 cities had a population over one million and 30 had a population between half a million and one million. Twenty-five years later, about 41 percent of China's 1.3 billion people were living in 660 urban areas, among which, 174 areas had population over one million, and 274 had a population between half a million and one million (National Bureau of Statistics, 2005; Song & Zhang, 2002).

Despite such rapid urbanization, today, about 760 million people are still living in China's

countryside. Tension caused by the growing wealth gap between urban and rural areas is one impetus for the Chinese government to push even more urbanization in order to create jobs for the un- and underemployed in the countryside. As new cities expand or emerge, the demand for urban transportation will continue growing.

To reduce transport-related energy consumption, China needs to learn from European cities and their wealthy Asian neighbors by restraining the use of private vehicles, and putting more emphasis on developing efficient and user-friendly transit systems. In an urban setting, driving a car is the most wasteful way of travel, for it takes at least twice as much energy as transit travel (with the exception of the U.S. bus system), and even more energy when compared with urban rail travel. The comparison is particularly striking (3.03 MJ for car versus 0.16 MJ for bus per passenger-km) for the wealthy Asian cities where highly efficient transit systems have been developed. Indeed, one of the main reasons why U.S. cities spend more transport energy for each dollar of wealth generated than European and wealthy Asian cities is because only a very small percentage (3.6 percent) of total passenger kilometers is on public transit. In contrast, about 23 percent of passenger km is on public transit in western European cities and over 64 percent in wealthy Asian cities (Newman et al., 1999).

Aware of the importance of public transport in providing mobility and reducing congestion in urban settings, the State Council issued a policy document in September 2005 requiring cities to give high priority to public transit when planning and developing their urban transportation systems. Many Chinese cities have invested to expand and improve their public transit systems. For example, by 2010, Beijing plans to spend at least 50 percent of its transportation improvement funds on public transit systems, and expects to double the length of its public rail system (to reach 250-300 km, including train, subway, and light rail), and to build a 60-km bus rapid transit (BRT) system. By 2010, travel on public transit is estimated to account for at least 40 percent of total travel in the downtown area (Beijing Transportation Committee, 2004). Nevertheless, like most Chinese cities, Beijing has no intention of restricting personal car ownership. In contrast, Shanghai has restricted personal vehicle ownership by limiting the total number of new vehicle licenses, and it also plans to adopt fiscal policies such as high cordon prices and parking fees to moderate traffic in the near future.<sup>32</sup> At the same time, Shanghai also

put much effort to improve its public transit services by building efficient subway and light rail systems and expanding the service area of public buses.

## CONCLUSION

Developing a less oil-dependent transport system is critical in reducing China's thirst for foreign oil, and a range of options and strategies can be utilized towards this end. China and other countries are beginning to recognize that reducing energy consumption in road transport without compromising mobility needs should be one of the fundamental goals of sustainable transportation.

Compulsory fuel efficiency standards are essential to push automobile manufacturers to provide more efficient vehicles—China's new fuel economy standard is a good step in this direction. Yet, the standards need to be strengthened if China would like its new vehicle fleet to achieve fuel efficiencies comparable to Japan and the EU. China also has started employing fiscal policies—e.g., excise tax for LDVs—to influence consumer's decisions on the type of vehicle they purchase. Yet a significant difference in transport fuel consumption is only possible if China imposes a steep fuel tax.

While alternative fuel vehicles can help mitigate oil security concerns, their potential in China is limited. LPG and natural gas are clean energy solutions, but supplies must be imported. Conversely, biofuels—particularly coal to liquids (CTL)—have a greater potential to address China's oil security concerns. However, without carbon capture and sequestration, CTL will lead to additional CO<sub>2</sub> emissions. China needs to overcome high production costs, limited technology capability and low infrastructure readiness to make the alternatives commercially competitive and environmentally sound.

Overall, less energy- and land-intensive travel alternatives must be sought out to meet the increasing demands from China's urbanization process. With new urban areas yet to be developed, China has the opportunity to integrate land use and transportation development to achieve the goal of minimizing future energy demand, as well as environmental, and social impacts from urban transport.

While such steps will certainly help China reduce its oil dependence, it is clear that global pressures on an increasingly tight global supply cannot be eased by one country alone. Other major oil consumers who share a common interest in viable oil prices, secured sea-lanes, and a stable international environment,

must also take steps to reduce their oil dependence. The United States in particular is the largest consumer and importer of oil in the world, along with being the most inefficient in its vehicle fleet. The U.S. transportation sector alone accounts for two-thirds of its total oil consumption, and it consumes about 17 percent of global oil produced annually. Actions to curb transport sector oil demand are long overdue in the United States. Many actions required by both China and the United States to reduce their oil demand are similar; ample opportunities for collaboration exist and ought to be explored.

U.S.-based automakers have lagged behind their Japanese and European counterparts in offering consumers highly fuel-efficient vehicles. The Chinese market is young and yet to be shaped; U.S. companies should take this opportunity to work closely with their Chinese partners to develop and produce vehicles that suit their Chinese consumers, use fuel frugally, and generate little emissions. The two nations should identify and undertake meaningful steps to facilitate the deployment of fuel-efficient vehicle technologies and collaborate on developing key technologies for producing biofuels (such as cellulosic ethanol).

The U.S. society is highly dependent on inefficient transportation modes and unsustainable energy needs; Chinese decision-makers should heed the lessons from the U.S. experience, for China's current path has serious environmental and health ramifications. The United States has a wealth of experience in vehicle emissions control that it could share with China; this would also help further strengthen bilateral relations between the two nations.

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## NOTES

1. China's energy intensity has dropped significantly (by two-thirds) during the same period (EIA, 2005b).

2. In 2005, coal contributed to about 70 percent of China's primary energy supply, while natural gas accounted for less than 3 percent; in the United States oil, natural gas, and coal accounted for about 40, 24, and 25 percent, respectively, of its total primary energy supply (British Petroleum, 2006).

3. From 1996 to 2003, China's total consumption of gasoline, diesel, and fuel oil increased by about 30, 80, and 20 percent, respectively (National Bureau of Statistics, 1998 & 2005). It should be noted that in 2004, road transport accounted for 86 percent of gasoline consumption in China, while it only accounted for one quarter of diesel consumption (China Automotive Technology and Research Center, 2006b).

4. CSM Worldwide, an international automotive consulting company, predicted that China's total car production would reach 8 million around 2010 ([www.csmauto.com/automotive-forecasts](http://www.csmauto.com/automotive-forecasts)); Han (2005) estimated that vehicle production will reach 8 to 10 million by 2010, and 14 to 18 million by 2020.

5. Non-motor travel modes still account for over 40 percent of travel in China.

6. Motorcycles are not included here.

7. Other similar studies anticipate much higher growth rates for China's national vehicle fleet; the International Monetary Fund (2005) predicts that China's total vehicle population will reach 210 million in 2020. Using South Korea as a reference case, Ng and Schipper (2005) estimated that China's car population alone will reach 146 million in 2020.

8. He et al., (2005) assumed a moderate increase of China's total vehicle population over the next twenty-five years; in which case the national vehicle fleet would then be less than 65 million in 2020 and 120 million in 2030 (Walsh, 2004).

9. Chinese fuel economy standards (Phase II) for vehicles lighter than 4,642 pounds (2110 kg) are more relaxed than current Japanese standards (by 4 to 20 percent), but those for heavier vehicles are more stringent (by 15 to 20 percent) than equivalent ones in Japan.

10. Continued models will have a one-year grace period to meet both Phase I and Phase II.

11. During the mid-1980s to the mid-1990s, vehicle fuel economy remained flat due to low oil prices.

12. A full hybrid system has a battery voltage over 300 volts and can sometimes run solely on the battery.

13. Diesel engines generally emit less HC and CO but much more particulates and NOx than gasoline engines. Diesel engines are not widely used in cars sold in the United States, partially because the U.S. Tier II emission standard for NOx is very expensive for diesel cars to meet. Replacing a Euro II, III, and IV gasoline car with a diesel car will triple NOx emission from that car over its lifetime. Particulate emissions are likely to increase by orders of magnitude. Controlling PM and NOx emissions are the most critical and difficult issues for air quality improvement in many Chinese cities. Advanced technologies for controlling particulates and NOx emissions from diesel vehicles demand ultra-low sulfur diesel (sulfur content is less than 15 ppm), which is not likely to be available in China at a large scale in the near future.

14. In 2000, the European motor vehicle industry accounted for 19 percent of total manufacturing R&D expenditure; its U.S. counterpart contributed to 15 percent of total manufacturing R&D; and, the Japanese, 3 percent (European Commission, 2004).

15. The real cost of driving a car has dropped in all countries since the early 1980s, which has increased car ownership and fuel use by private cars worldwide. Nevertheless, the United States stands out for much higher vehicle distance traveled per capita and transport fuel consumption per capita (IEA, 2003).

16. Singapore also adopted an electronic road pricing system to moderate traffic flow at chokepoints of expressways and artery roads during peak hours (e.g., time-variable tolls). At the same time, Singapore invested heavily in mass rapid transit service and integrated bus systems to make public transit attractive.

17. The tax does not apply to light trucks. Today, the only cars in the United States subject to the gas-guzzler tax are high-priced, low sales volume, luxury and performance cars.

18. It is not very clear what percentage of fuel price is attributed to taxes in China. The National Development and Reform Commission has the authority to set the "guidance prices" of gasoline and diesel at the refinery gate, which are supposedly linked to the trading prices of gasoline and diesel in the Singapore, Rotterdam, and New York markets. The two largest Chinese oil companies, China National Petroleum Corporation (CNPC) and China Petrochemical Corporation (Sinopec), which together own over 90 percent of China's total refining capacity, determine the actual wholesale price within an 8 percent range of the guidance prices. Because the regulated prices of gasoline and diesel did not rise consistently with soaring crude oil prices, CNPC and Sinopec claimed that their refineries had suffered several billion dollars of loss in 2005.

19. Excise taxes are collected from vehicle manufacturers directly but they are ultimately reflected in the prices of vehicles.

20. As one of China's promises for entering the WTO, vehicle import tariffs dropped from 28 to 25 percent on 1 July 2006 ("Car makers greet 2005," 2005).

21. People who want to register a vehicle in Shanghai must bid for a license. The mean bidding price of new licenses reached \$2,600 in Shanghai in June 2006.

22. The new excise scheme is criticized for simplifying the relation between engine size and fuel efficiency, i.e., vehicles with larger engines are not necessarily less efficient than those with smaller engines. Policy analysts in China are now discussing a potential adjustment of purchase taxes to reflect fuel efficiency of vehicles directly.

23. Hainan Province combined road maintenance fees, tolls, and vehicle management fees into one fuel tax. Rampant gasoline smuggling occurred because of the big discrepancy between the gasoline price in Hainan and that in its cross-strait neighboring province Guangdong (Jia, 2005).

24. Other ministries and the State Environmental Protection Administration were involved in the program.

25. MoST is also interested in LNG vehicles. Because LNG must be stored at about  $-160^{\circ}\text{C}$  ( $-260^{\circ}\text{F}$ ), sophisticated containers are needed to minimize boil-off, which makes the technology unattractive for passenger vehicles but feasible for large vehicles such as trucks and buses.

26. China has relied on foreign sources for its LPG needs (over a quarter of its demand was met by import

in 2005), and it will have to import large quantities of natural gas by 2010 (IEA, 2004).

27. In 2005, about 40 percent of the fuel sold in Brazil was ethanol (REN21, 2005). Brazilian companies are able to produce ethanol from sugar cane at a very competitive cost—its ethanol is currently sold at less than half the gasoline price at the pump ("A tankful of sugar," 2005); to encourage auto companies to produce vehicles running on "flex fuel" (e.g., can run on pure ethanol, pure gasoline, or gasohol—a mixture of 25 percent ethanol and 75 percent gasoline), the Brazilian government extended tax incentives for ethanol-only vehicles to flex fuel vehicles (Rohter, 2006).

28. These nine provinces are Anhui, Hebei, Heilongjiang, Henan, Hubei, Liaoning, Jiangsu, Jilin, and Shandong.

29. The central agencies and companies negotiated subsidies at different levels for different years. For example, Jilin Fuel Ethanol Company enjoyed a subsidy at 2,763 Yuan per ton of ethanol in 2004, the first year of its production operation (Zou & Li, 2006).

30. See the studies by Hill et al. (2006) and Hammerschlag (2006). In contrast, the energy balance of sugar cane ethanol is much superior (8.3) (Rohter, 2006).

31. In addition, China has also engaged in research on electric and fuel cell vehicles. Nevertheless, wide use of electricity or hydrogen as energy carriers for vehicles is unlikely to be fulfilled in the near future.

32. As a result, the total number of vehicles registered in Shanghai was controlled at about 1 million in 2005, 60 percent less than the total number of vehicles registered in Beijing.

## Ecological Behavior among Adolescents in Hangzhou

By Jun Yu and Jocelyn Eikenburg

Following Zhejiang Province's 2002 call to "green" the province by promoting more sustainable development, the provincial capital Hangzhou decided in February 2003 to promote programs to make it an ecologically friendly city. This goal requires not only support from the government, but also participation from individuals—particularly adolescents, for while they are unlikely to be involved in pressuring government and industries for better enforcement of pollution and conservation regulations, their impact on protecting the environment could be considerable. Specifically, if adolescents learn to incorporate more ecological values and behaviors into their daily activities—e.g., saving energy and reducing waste—they help lessen their individual ecological footprint and adopt habits that will last a lifetime. Public participation to protect the environment is not simply accomplished by participating in environmental impact assessment hearings or protesting on the street, but also by changing personal consumption of resources.

After the "ecological city" campaign had been underway for two years, we were curious as to how "green" adolescent students were in Hangzhou. Thus, in October 2004, as part of Shanghai Normal University Professor Cen Guozhen's values research project (funded by China's Ministry of Education), we surveyed 1,178 students in Hangzhou between the ages of 12 and 24. Our 14 survey questions created a daily ecological behavior scale reflecting three facets of ecological behavior: (1) environmental protection (2, 6, 7, 11, 12); (2) protecting wild plants and animals (5, 8, 9, 13, 14); and (3) resource conservation (1, 3, 4, 10). The percentage distributions for responses to each of the 14 questions are shown in Table 1.

Overall, most respondents performed many of these daily ecological behaviors, except for 6

(battery recycling), 8 (tree-planting) and 10 (paper/plastic/metal recycling). These low responses could be due to the limited scope or outreach of recycling programs in Hangzhou. If such facilities exist, but students do not know how or why they should use them, they obviously cannot make recycling a part of their daily lives. In terms of tree planting, not every school has such programs and some areas may not even have land available on which to plant trees.

The best response was for four questions—turning off lights (1) and water (3); double-siding paper (12); and protecting trees (13). These four were clearly the "low hanging fruit" of ecological behaviors, in part because schools emphasize such behavior. Nevertheless, there were six items (2, 6, 7, 8, 10, 14) spanning all three ecological behavior facets, in which there was not a plurality of respondents choosing the frequency "always." Thus, it seems doubtful that the students surveyed integrated a broad range of ecological behaviors into their way of living.

The survey revealed that among the three facets of ecological behavior, students perform the best in resource conservation, followed by protecting wild plants and animals, and worst in environmental protection. Students may pay more attention to resources such as water and electricity because they are more interested in that which they use in their daily life. Animals and plants may arouse emotions such as care and love, which can motivate them to act ecologically. But environmental protection has a much wider range—including water, air, soil and noise pollution. Students may feel they have little control over such issues, which lowers their sense of responsibility and desire to take action.

So how can Chinese society get students more environmentally involved? First, the government

TABLE 1. Frequency Distribution for Daily Ecological Behavior Scale

	<b>How often do you perform the following behaviors?</b>	<b>Never %</b>	<b>Rarely %</b>	<b>Sometimes %</b>	<b>Always %</b>
1	Turn off the light when it is not in use	.4	2.6	15.5	81.5
2	Separately dispose of garbage when there is a sorted garbage can	5.7	23.4	36.9	34.0
3	Turn off the water while brushing teeth	2.1	5.4	15.1	77.3
4	Use refillable pens	5.6	16.2	26.1	52.1
5	Refuse to eat wild or exotic animals	5.4	9.5	22.9	62.3
6	Recycle used batteries	10.8	28.7	34.0	26.5
7	Refuse to buy products that are not environmentally friendly	2.2	16.1	36.3	45.4
8	Participate in tree-planting activities	20.6	43.0	25.1	11.3
9	Refuse to use products made from wild or exotic animals	6.1	13.2	23.1	57.5
10	Recycle paper, plastics and metals	22.5	31.8	25.5	20.2
11	Dispose of garbage only when there is a garbage can available	2.9	8.0	24.4	64.7
12	Use both sides of a piece of paper	2.1	9.1	23.7	65.2
13	Protect and not damage young trees	.9	2.5	16.4	80.2
14	Protect and avoid stepping on flowers and grass	2.5	9.5	44.8	43.2

needs to make opportunities available for the schools and their students. As local governments expand recycling programs, they should work with non-governmental organizations (NGOs) and schools to promote strong public outreach and education. Similar partnerships could enhance organic and green farming. Schools, NGOs and local governments could jointly organize more environmental activities to broaden opportunities for young people to be “green.” Examples include tree planting, nature walks, outdoor environmental studies, visits to environmental facilities such as recycling centers or organic farms, lectures from environmental professionals, and open discussion forums. Another promising avenue would be to encourage

the creation of student environmental groups in elementary, middle, and high schools, which could link up with various domestic and international NGO programs, such as Roots and Shoots, WWF-China, and local university student environmental associations. Cultivating environmental education with Chinese youth could create a whole generation of more ecologically conscious individuals.

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