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China Motorization Trends: Policy Options in a World of Transport Challenges

Wei-Shiuen Ng ● Lee Schipper

1. INTRODUCTION

As the fastest growing large economy in the world, China is experiencing a rapid increase in motor vehicle ownership and use, in the process gaining immense economic and personal mobility benefits. However, this explosion in car ownership is unsustainable, as evidenced by the impacts of rising congestion, increased air pollution, increased oil consumption, and high rates of traffic fatalities. A sustainable transportation system would meet the increasing demand for private motorization without compromising the economic and welfare gains from greater mobility. The rapid growth of private vehicles in China, which will no doubt increase in ownership and use, threatens this sustainability, even though private vehicles currently contribute as little as 10 percent of the total daily trips in most cities.

Scenarios are used in this chapter to illustrate, but not predict, how a series of assumptions can lead to different outcomes. The scenarios show how effective mobility management, with the aid of advanced and alternative fuel vehicle technologies, could reduce oil consumption and many of the impacts of rapid private motorization that threaten sustainability. In addition, advanced fuel and vehicle technologies and approaches could help reduce the conflict between the economic development and environmental sustainability goals of the country by providing relatively smaller, safer, and cleaner vehicles to meet the growing demand. The forecasts of high private motor vehicle ownership and the subsequent oil demand imply enormous strains on urban infrastructure, as well as energy imports. These strains would be much easier to avoid with sustainable transport policies enacted now, rather than being rectified one or two decades later.

This chapter explores existing and potential Chinese transport and energy policy options related to private individual motor vehicles that have been or may be implemented in response to energy security, air pollution, and other challenges associated with motorization. It develops three different personal mobility scenarios that project oil and energy demand outcomes in 2010 and 2020, revealing a wide range of future oil demand levels and potential oil imports. The results also translate into a wide range of future carbon emissions from personal transportation. These outcomes depend primarily on choices Chinese...
policymakers make now. Different policy options are linked to the scenarios, suggesting how different policies could affect vehicle use, as well as how advanced and alternative fuel vehicle technologies could reduce some of the negative impact of motorization and improve energy efficiency.

Section 2 describes motorization trends in China and the energy and environmental consequences that follow. Section 3 reviews current transport-related policies, targets, and standards in China. The scenarios and key results are explained in sections 4 and 5. Policy options that could create the optimal transport scenario are presented in section 6. Section 7 provides the final discussion and conclusion.

2. TRANSPORT TRENDS AND CHALLENGES IN CHINA

2.1 The rise of the transport sector

Transportation in China today is dominated by public transit and traditional transport modes. Public transport carries approximately 50 percent of all urban trips in China, with cycling and walking carrying another 40 percent (Schipper and Ng, 2005). Most Chinese cities have good transport systems built on buses, metros, and local rail systems that are extended to a greater region. Virtually all intercity (long-distance) travel is by rail or air. The average Chinese person travels about 1,000 kilometers (km) per year, compared with averages of 15,000 km per year for Europeans and over 24,000 km per year for Americans. Although mobility in China (measured in annual personal travel) still has a long way to grow, increases in travel distance do not always imply social benefits, as the benefits of private motorization could be easily exceeded by its incurred high costs (The National Academies, 2003).

One reason for low mobility is the low number of motor vehicles. In 2004, there were only 27 million privately owned motor vehicles in China (Brown, 2004), with most of them concentrated in large Chinese cities. The total number of cars—private and state-owned—was approximately 12 million, or 9 cars per 1,000 people, far below the global average (He et al., 2004). By comparison, there are over 700 cars (including personal vans, light trucks, and SUVs) per 1,000 people in the United States, 400 in Japan, 350–500 in Europe, and 150–200 in middle-income countries like Mexico, Brazil, and Korea. Motorized mobility in China, however, is set to change significantly as private car ownership takes off.

The growth of the transport sector in China accelerated markedly after 1978, when the country underwent massive policy reforms leading to significant economic development, industrialization, and urbanization. These changes have resulted in rapid increases in motorization and urban mobility. If lessons from the rest of the world apply to China, existing transport modes will face increasingly stiff competition from individual cars. With an increasing number of middle-class families, car ownership is no longer restricted to a selective group of governmental officials and high-income families. National passenger car sales increased by 76 percent from 2002 to 2003 while, over the same period, passenger car production increased by 86 percent (CATARC, 2004).

Given its large population and the small absolute number of vehicles in China, present trends point to enormous increases in motor vehicle ownership and fuel use. China appears to be following a path defined by other diverse nations. Figure 1 portrays motorization in relation to income. On a per capita basis, China’s motorization in 2003 (the point farthest to the right and highest for China) is comparable to the U.S. in 1907, though China’s per capita GDP in 2003 was only half of U.S. levels in 1907. The last dozen points for China in Figure 1 (bottom left) are very close to the first dozen points for Korea (from the 1970s), which fall somewhere between those of West Germany and Japan, when Korea was at income levels that those countries achieved in the 1960s and 1970s.

Rapid growth in motorization is bringing both costs and benefits to Chinese societies (Schipper and Ng, 2005). Benefits include economic growth—due to better accessibility for commercial, public, and private transport—and improved social welfare as a result of increased flexibility and mobility. Costs are incurred in areas such as energy consumption and security, environmental and health impacts, congestion, and traffic fatalities.

2.2 Energy consumption and security

Energy consumption and oil imports, which are increasingly driven by the transport sector, have raised concerns over energy security. In 2003, China consumed approximately 275 million metric tons of oil, of which 30 percent was imported (BP, 2004) (Figure 2). The increase
in energy consumption has resulted in China’s transformation from an oil exporter prior to 1993 to a large net oil importer. Absent specific measures, the demand for crude oil is expected to increase by 12 percent annually until 2020 (He et al., 2004).

The Chinese transport sector, which is almost entirely dependent on oil, is increasingly a leading driver of overall consumption increases, contributing more than one-third of China’s total oil consumption in 2002 compared to about 16 percent in 1980 (IEA, 2004b). From 1990 to 2002, gasoline and diesel consumption in the transport sector increased 157 percent (IEA, 2004b). Within the transport sector, it is notable that private car use constitutes a relatively small share of China’s oil consumption—about 10 percent in 2001 (Figure 3). In the ensuing three years, however, the number of cars in China increased by 75 percent. As motorization trends continue, the share of oil consumption from cars will quickly become dominant.

2.3 Environmental pollution

Pollutants produced during the combustion of gasoline or diesel fuel in vehicle engines have major environmental impacts. Such pollutants include carbon monoxide (CO), ozone (O₃), volatile organic compounds (VOCs), nitrogen oxides (NOₓ), and fine particulate matter (Walsh, 2003a). Respiratory diseases such as infections, asthma, and decreased lung efficiency are common in polluted urban cities (Stares and Liu, 1996), in addition to reduction in

![Figure 1. Comparison of Car/Light Truck Ownership in U.S., China, Korea, Japan, and West Germany](image1.png)

Notes: The horizontal axis shows per capita GDP converted to US$ at purchasing power parity (PPP). The range of years for each country covered by this GDP range is shown in the legend. Source: U.S. Federal Highway Administration (various years), National Statistical Abstracts and Transportation year books (vehicles), International Energy Agency Energy Indicators Data base (vehicles for West Germany and Japan) and OECD (for PPP conversions, GDP, and population data).

![Figure 2. Oil Production, Consumption, and Exports in China](image2.png)

pulmonary function. These public health impacts will not only lead to losses in individual welfare, they could also inflict substantial economic costs upon the society.

Air pollution from industry and households is gradually declining; as a result, vehicular emissions comprise a high and rising proportion of total urban air pollution in many Chinese cities (Table 1). Studies have shown that 45-60 percent of NO\textsubscript{x} emissions and 85 percent of CO emissions are from mobile sources in most Chinese cities (Walsh, 2000). It is estimated that by 2010 in Shanghai, vehicular emissions will produce 75 percent of total NO\textsubscript{x} emissions, 94 percent of total CO emissions, and 98 percent of total hydrocarbon (HC) emissions (Wang and Wu, 2004). Even with improved emissions controls and cleaner fuels, mobile-source pollution in Chinese cities is likely to continue rising due to increased use of individual vehicles and the total distance traveled.

### Table 1. Motor Vehicle Shares of Criteria Pollutants in Chinese Cities

<table>
<thead>
<tr>
<th>City</th>
<th>CO (%)</th>
<th>HC (%)</th>
<th>NO\textsubscript{x} (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing (2000)</td>
<td>77</td>
<td>78</td>
<td>40</td>
</tr>
<tr>
<td>Shanghai (1996)</td>
<td>86</td>
<td>96</td>
<td>56</td>
</tr>
<tr>
<td>Guangzhou (2000)</td>
<td>84</td>
<td>50</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Adapted from Mao et al. (2001)

3. CHINA’S TRANSPORT-RELATED PRIORITIES AND POLICIES

The Government of China has enacted various policies and regulations relating to transportation and fuel use. These are targeted at improving ambient air quality in urban cities, reducing congestion, and improving transport energy efficiency. Many of these policies will reduce the impact of each kilometer driven or traveled in China. Policies are also targeted, however, at promoting the development of the automobile industry and greater domestic consumption of motor vehicles. The challenge for China is to resolve the tensions between these competing priorities and policies.

#### 3.1 Developing the automobile industry

The Chinese automobile industry has been one of the most rapidly growing in the world; China now ranks as the world’s third largest automobile producer. Over the 1999 to 2004 period, Chinese production of motor vehicles increased by 177 percent, from about 1.8 to 5.7 million vehicles per year (OICA, 2005). China’s share of global production in terms of quantity has risen from 3.3 percent to almost 8 percent in five years. The automobile industry has been a “pillar” of economic development since 1988; this role has been reaffirmed by the government in preparing its 11th 5-year plan (2006-2011).

The development of the Chinese automobile industry has resulted in significant economic benefits. The sector has employed 1.8 million people and has total assets of $61.3 billion (The National Academies, 2003), as well as receiving significant levels of foreign direct investment (Gallagher, 2003). Total investment in new automobile manufacturing capacity in China is projected to reach $25.5 billion by 2007 (Xinhuanet, 2004a).

The rapid growth and development of the Chinese automobile industry has resulted in a new auto industry policy, which was launched by the National Development and Reform Commission in June 2004 (Xinhuanet, 2004b). This policy is aimed at slowing investment and consolidating the auto industry, which has been one of the most over-invested industrial sectors in China—mainly because of massive investment from foreign automakers and domestic state and private enterprises. New restrictions will include the regulation of new foreign investors entering the market. Nevertheless, foreign investors will still play an important role in the production of vehicles in the Chinese automobile industry.

Another goal of this policy is to further develop an automobile market largely dominated by private consumption, rather than state-owned vehicles. As the benefits of worldwide production practices and lower-priced...
advanced automotive technologies are now available in China, cars have increasingly become more appealing to Chinese consumers. However, the type of vehicle technologies likely to dominate the market is still uncertain. The 2004 auto industry policy also supports alternative fuel and advanced vehicle technologies, and it is expected that research and development in these areas will increase.

3.2 Saving transport energy

The need and urgency to restrain the growth in energy demand has become a national priority in recent years, mainly due to the experience of frequent energy shortages since 2000, brought on by China’s booming economy. China, which now ranks as the world’s second largest energy consumer after the U.S., has introduced energy conservation plans and increased public awareness of energy conservation. The recently agreed Chinese 11th 5-year national plan has restated and strengthened this commitment to improved energy efficiency.

Premier Wen Jiabao has announced that China will build an energy-saving society and implement state policies to promote efficient technological processes and encourage sustainable consumption through economic restructuring (Xinhuanet, 2004c). Accordingly, energy-efficiency policies for industry and the transport sector are expected to increase. Overall, energy demand will still rise with China’s near double-digit economic growth, but economic growth could continue to outpace energy demand if energy conservation policies increasingly take hold. This has generally been the case since the 1980s, largely as a result of industrial modernization.

Policy changes are reflected in the 2004 National Energy Policy, which has shifted the focus from energy exploitation to energy conservation and improving energy efficiency, when compared with the previous energy policy implemented in 1998. The National Energy Policy launched a long-term energy-saving plan and is currently the biggest and most ambitious energy-saving plan in China’s history (Mai, 2004). The burden to reduce energy consumption will no doubt be distributed across all industries and sectors, including the transport sector, which, as noted, is becoming a significant oil consumer.

The fuel economy standards announced in October 2004 are a key regulation to aid energy security. These standards require the auto industry to produce more fuel-efficient vehicles, which could include cleaner advanced vehicles or alternative-fuel vehicle technologies. The first phase of the standards will be implemented for newly introduced vehicles sold from July 1, 2005. For continued vehicle models, vehicles sold must meet the same standards by January 1, 2006. A stricter second phase for new car models entering the Chinese market will be in effect by January 1, 2008 (An and Sauer, 2004).

These standards establish maximum fuel intensities (fuel per km) for new vehicles, which are a function of weight and transmission type. For passenger vehicles weighing less than 750 kilograms, the maximum new vehicle fuel intensity is 7.2 liters of fuel per 100 km (equivalent to 33 miles per gallon [mpg]) for a vehicle with manual transmission and 7.6 liters/100 km (32 mpg) for vehicles with an automatic transmission. Permitted fuel intensity then rises with new vehicle weight in 15 additional weight classes.

Future uncertainties regarding consumer preferences and vehicle weights make it difficult to evaluate the overall likely impact of the fuel economy standards. A shift toward lighter cars could lead to lower average fuel intensity than those required by the standards alone. The 2003 average new vehicle weight in China was about 1,500 kilograms (Sauer and An, 2004), which is considered heavy by international standards. The prominent share of large imported cars and SUVs in the sales mix over the past five years may contribute to this high average vehicle weight. As seen in many other countries, the weight and engine size of new vehicles tends to increase as income rises. Because China’s fuel economy standards are weight-based, they would not inhibit such a trend. However, it is unclear if this will apply to China, as an increasing number of smaller vehicles are being purchased by the growing group of middle-class households.

3.3 Reducing air pollution

Through a series of legislative acts, regulations, and standards, the Chinese government has responded to the growing air pollution and public health risks described in section 2.3. These include national ambient air quality standards for different air pollutants, emission standards, and fuel quality standards. Generally, the established legislation states that the national government is responsible for measures to control air pollutants, while local governments have the responsibility for implementation and enforcement (Wang and Wu, 2004).
The 2000 Chinese Clean Air Act requires motor vehicles to meet emission standards and prohibits the manufacture, sales, or import of motor vehicles that have levels higher than the standards set by the State Environmental Protection Administration (SEPA). The 2002 Clean Air Act also encourages the development and sale of clean fuels for motor vehicles. The enforcement of the Clean Air Act and other requirements, however, is still weak, especially when certain regulations are not comprehensive enough.

Because air pollutants from mobile sources are highly dependent upon fuels, improving fuel quality is an important approach to reducing mobile source emissions. The “Emission Standard for Exhaust Pollutants from Light-Duty Vehicles” was implemented in 1999 by SEPA and went into effect in January 2000. This law set emissions standards equivalent to Euro I standards (He and Cheng, 1999). Increasingly, China is following emission standards regulations from the United States, Europe, and Japan, even though the level of control (i.e., grams per km permitted) and enforcement is still less stringent in China. The government nevertheless recognizes the need to improve its air quality and has implemented Euro II equivalent fuel quality standards in Beijing and Shanghai in 2003. SEPA in Beijing has also charted emission standards that are equivalent to Euro III and expects the entire country to adopt the Euro III level by 2008 (Li, 2004).

Table 2 shows the European Union emission standards for passenger cars and their year of implementation. Other transport policies, such as those that restrain automobile use, will of course also have air pollution benefits.

3.4 Public transportation

According to the 2004 National Energy Policy, public transportation—buses and taxis—should be the main access method in big cities, with rail transportation supporting the transport network, while personal cars and bicycles should be used as supplements. In medium and small cities, public transportation will be developed, as well as the use of personal cars.

Public transport systems are in high demand in megacities, as well as middle-sized cities, where some are already actively adopting urban transport policies that encourage public transport. For instance, municipal authorities in Shanghai are now putting a high priority on buses and are seeking to increase public transport travel volume (People’s Government of Shanghai Municipality, 2002). Overall, the Government of China is publicly encouraging the construction of bus rapid transit (BRT) and other public transit modes. Beijing is projected to have an increase of 100 kilometers in BRT bus routes, leading to a total length of 360 kilometers for the entire network by 2008. Kunming, Shanghai, Xi’an, Chengdu, Chongqing, Tianjin, Hangzhou, and Shenyang are either already in the process of developing BRT systems, planning BRT designs, or awaiting approval for their BRT proposals.

3.5 United Nations Climate Convention commitments

As a party to the 1992 Framework Convention on Climate Change and 1997 Kyoto Protocol, China has also committed to taking steps to limit greenhouse gas (GHG) emissions. Developing countries do not have quantified emission limitations under these agreements, though all countries have committed in the Convention to implement policies and measures to mitigate climate change (UNFCCC, 1992, Art. 4.1b). The Kyoto Protocol affirms these obligations for developing countries and also adds some additional detail by specifying particular sectors—including transport—where measures might best be targeted (UNFCCC, 1997, Art. 10b).

In 1990, China set up a National Climate Change Coordination Committee—composed of 15 government departments and institutions—to look at policymaking and scientific research (Qin and Zhu, 2004). China has also completed and submitted its first national communications to the UNFCCC, which includes a GHG inventory, and is increasingly engaged in emission-reducing projects through Kyoto’s Clean Development Mechanism. With respect to policies, a number of existing policies and measures in the transport sector, such as the fuel intensity standards for new vehicles, are likely to have beneficial effects on CO₂ emissions. Many of the policy approaches

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Table 2. EU Emission Standards for Passenger Cars (grams per km)

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>CO</th>
<th>HC</th>
<th>HC+NOₓ</th>
<th>NOₓ</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euro I</td>
<td>1992</td>
<td>2.72</td>
<td>–</td>
<td>0.97</td>
<td>–</td>
<td>0.14</td>
</tr>
<tr>
<td>Euro II</td>
<td>1996</td>
<td>1</td>
<td>–</td>
<td>0.7</td>
<td>–</td>
<td>0.08</td>
</tr>
<tr>
<td>Euro III</td>
<td>2000</td>
<td>0.64</td>
<td>–</td>
<td>0.56</td>
<td>0.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Euro IV</td>
<td>2005</td>
<td>0.5</td>
<td>–</td>
<td>0.25</td>
<td>0.25</td>
<td>0.025</td>
</tr>
<tr>
<td>Euro V</td>
<td>mid-2008</td>
<td>0.5</td>
<td>–</td>
<td>0.25</td>
<td>0.2</td>
<td>0.005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Petrol (Gasoline)</th>
<th>Date</th>
<th>CO</th>
<th>HC</th>
<th>HC+NOₓ</th>
<th>NOₓ</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro I</td>
<td>1992</td>
<td>2.72</td>
<td>–</td>
<td>0.97</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Euro II</td>
<td>1996</td>
<td>2.2</td>
<td>–</td>
<td>0.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Euro III</td>
<td>2000</td>
<td>2.3</td>
<td>0.2</td>
<td>–</td>
<td>0.15</td>
<td>–</td>
</tr>
<tr>
<td>Euro IV</td>
<td>2005</td>
<td>1</td>
<td>0.1</td>
<td>–</td>
<td>0.08</td>
<td>–</td>
</tr>
<tr>
<td>Euro V</td>
<td>mid-2008</td>
<td>1</td>
<td>0.075</td>
<td>–</td>
<td>0.06</td>
<td>0.005</td>
</tr>
</tbody>
</table>

outlined in the sections that follow would likewise contribute significantly to China’s national priorities on energy security and air pollution, but also to China’s obligations under the UNFCCC.

4. FUTURE MOTORIZATION AND MOTOR VEHICLE USE TRENDS IN CHINA: THE SCENARIOS

The future of the Chinese transportation sector is difficult to model or predict. There is inadequate data on fuel use, car ownership, fuel economy, and driving habits, among other parameters. Even when data is available, it may be unreliable, in part because future car owners in China will be different from today’s. Historically, the majority of car owners and users were taxi and professional drivers, high functionaries, and company employees. Modeling their future behavior tells us little about how the average Chinese family will behave. Furthermore, discontinuities are expected, in part due to newly imposed fuel economy and emissions standards, policies to encourage alternative fuels, and other policies and conditions that could strongly reshape and regulate car use.

To better understand the future of the transport sector and the influence of policies, this chapter develops three scenarios that use different assumptions about the level of transport activity, vehicle size/characteristics, and vehicle technology. The scenarios are constructed in a bottom-up fashion, in part using parameters and extrapolations based on experiences in two countries, Japan and Korea (South). Each scenario is accompanied by policies (or lack of policies) that could plausibly lead to the outcomes we describe. These scenarios are accounting, not behavioral, models.

The main input assumptions for the scenarios are shown in Table 3. Fuel taxes, vehicle use fees, and other policies are not quantitative and are simply used as qualitative measures to trigger the other input assumptions in

<table>
<thead>
<tr>
<th>Table 3. Transport and Technology Scenarios Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenarios</td>
</tr>
<tr>
<td>Assumptions in the scenarios</td>
</tr>
<tr>
<td>GDP and Population</td>
</tr>
<tr>
<td>Motorization Rate of Increase</td>
</tr>
<tr>
<td>Car Characteristics (Weight)</td>
</tr>
<tr>
<td>Car Utilization - Distance Traveled (km/vehicle/year)</td>
</tr>
<tr>
<td>Fuel Choices</td>
</tr>
<tr>
<td>Assumptions made but not quantified in the scenarios</td>
</tr>
<tr>
<td>Fuel Taxes</td>
</tr>
<tr>
<td>Vehicle Use fees</td>
</tr>
<tr>
<td>Other Policies</td>
</tr>
</tbody>
</table>

Acronyms: GDP (gross domestic product); HEV (hybrid electric vehicle); CNG (compressed natural gas).
Box 1. Introduction to Advanced and Alternative Fuel Vehicle Technologies

1. Hybrid Electric Vehicles (HEVs)
HEVs are a cross between conventional automobiles and electric vehicles, combining an electric drive (motor and electricity storage) and an internal combustion engine. HEVs consume less energy by regenerating energy while braking, using smaller engines, allowing the engines to be turned off during stops, braking or coasting, and in some configurations, the motor alone can be used to accelerate from a stop (Santini et al., 2001). Apart from energy and oil savings, HEVs will also improve air quality and reduce CO2 emissions. HEVs are relatively less expensive to introduce to the market than other technologies such as fuel cells, as they do not require new infrastructures for fuel production and distribution (Wang, 2003). Plug-in hybrids are not considered in this chapter.

2. Compressed Natural Gas (CNG)
Vehicles powered by CNG, an alternative fuel, could reduce air pollution and reliance on oil. Per vehicle-kilometer traveled, CNG vehicles could emit 25 percent less carbon dioxide, 90-97 percent less carbon monoxide, and 35-60 percent less nitrogen oxide than conventional gasoline vehicles, depending on the engine design (US EPA, 2002). Other than being a cleaner fuel, CNG also has potential advantages with respect to cost, performance, and durability (due to a clean combustion process of natural gas) (US EPA, 2002). On the other hand, its fuel economy could be lower or identical to conventional gasoline vehicles (US DOE, 1999), and such vehicles generally have higher vehicle capital and infrastructure costs.

Natural gas is currently used for public vehicles, including buses and taxis in about 11 cities, including Beijing, Shanghai, Chongqing, Xi’an, and Sichuan. There are currently 50,900 natural-gas-fueled vehicles in China (He, 2003). When compared with the United States, which had about twice as many natural gas vehicles in 2003, the market penetration of natural gas vehicles is relatively higher due to China’s significantly lower number of total vehicles. Since CNG offers the most engine and vehicle diversities (Rubin, 2003), this market is likely to further expand as China searches for sustainable energy resources.

3. Small Conventional Gasoline Vehicles
For many decades, “mini cars” with displacement of less than 600cc were common in space-constrained Japan (Schipper and Kiang, 1995). More recently, a number of major companies, notably Mercedes Benz, have begun to develop somewhat larger “mini-cars.” Created by the stylish “smart” of Mercedes Benz and Swatch Group Ltd., these cars are popular for their small size and are fitted for urban parking and driving. At 40-60 mpg, these are some of the most fuel efficient internal combustion cars in the market and, at eight feet in length, small enough to back into a parallel parking spot, with two fitting in a single parking space. With aluminum engines weighing only 60 kilograms and a curb weight of about 730 kilograms (SMART, 2004), its light weight contributes to excellent fuel economy.

4. Small Electric Vehicles
Electric cars tend to have lower overall primary energy requirements per kilometer than gasoline cars of the same size (Delucchi, 2005), depending on primary energy sources. However, their lower speeds and performance means they will not be driven as much or as fast as conventional gasoline cars, thus indirectly contributing to energy savings. Small electric vehicles are most suitable for urban low-speed driving environments and could form a key component in creating a sustainable transport system. Electric vehicles are emissions-free at the point of use and could potentially transfer emissions to less populated and polluted areas (Lave et al., 1995), reducing transport emissions in urban cities. If the electricity used to recharge such vehicles is produced using efficient technologies and renewable energy resources, pollution and energy-saving benefits would increase.

Likewise, with future advancement on alternative battery technologies, energy and cost-efficiency would improve.

the scenarios. Box 1 includes summaries of the different vehicle technologies. A more complete description of the assumptions can be found in Appendix 1. The outputs of the scenarios—measured in energy and oil consumption, and resulting carbon emissions—are of course only as robust as the parameters and policies applied to the scenarios. These outcomes are not predictions, but by setting up three possible futures, we provide a picture of the potential impact of various technologies and other options that could significantly affect personal automobiles and their use.

4.1 Road Ahead
The “Road Ahead” (baseline) scenario assumes that the current growth rate of motorization continues. Conventional gasoline vehicles are the dominant vehicle technology, car use is not restricted, and no significant fuel taxes are implemented through 2020 as Chinese policymakers follow a pricing policy with minimal taxes. It is also assumed that no other vehicle or fuel policies other than fuel economy standards will be implemented and enforced. In this scenario, the market penetration of HEVs is 5 percent, CNG 2 percent, and small electric cars 0.5 percent by 2020. China’s level of motorization is derived from Korea’s, as suggested by Figure 1. China, in this scenario, reaches the same number of cars per unit GDP in 2020 as Korea when Korea had China’s projected 2020 per capita GDP in 1993. The best estimate of China’s on-road fuel economy today is 9.5 liters/100 km. In the Road Ahead scenario, this figure improves simply because of improved technology and the likely rise in demand for smaller cars (i.e., under 1,500 kilograms).

4.2 Oil Saved
“Oil Saved” is driven by a clear move to save oil, backed by phasing-in of fuel taxes until they reach the level of those in Japan in early 2005, at approximately $2.70/gallon (Oil Market Report, 2005). Apart from conventional gasoline vehicles, CNG fuels 20 percent of cars by 2020, obtaining 5 percent better fuel economy (US DOE, 2005), and small electric vehicles power 10 percent, using less primary energy than gasoline or even CNG vehicles. In this scenario, there are 10 percent fewer cars than in Road Ahead, consistent with the small effect of higher fuel prices on car ownership observed by Johansson and Schipper (1997). Spurred by higher fuel prices, fuel economy improves much faster than in Road Ahead. This encourages a market share of 15 percent HEV by 2010 and a more significant 50 percent by 2020. The hybrid vehicles use only 80 percent of the fuel per km of conventional gasoline cars, a figure that falls to 75 percent by 2020 as technology improves. Higher oil prices will push car use downward, implying that 25 percent of all vehicles sold in the 2006–10 period are hybrids.
The assumptions used are consistent with experience in Europe, where the price elasticity of car use is within the range from -0.2 to -0.3 (Johansson and Schipper, 1997). Since real fuel prices in Oil Saved are roughly 2 to 3 times higher than in the Road Ahead scenario, which used 2003 prices, annual distance traveled is reduced by roughly 40 percent over its initial value, arriving at 10,238 km per vehicle by 2020. The fact that car use does not further decrease is a reflection of an improvement in fuel economy.

4.3 Integrated transport

The “Integrated Transport” scenario is a result of thoughtful and successful resistance to congestion by the Chinese authorities. The outcome is bolstered by the popularity of very small gasoline and electric cars whose required road space is less than that of conventional cars, and parking space significantly less. Additionally, such small cars are not as fast as conventional cars; hence, the overall utilization per car in this scenario is the lowest in all three scenarios. In this scenario, small and highly efficient vehicles will play a considerable role in reducing fuel consumption. Hybrids—together with small gasoline, electric, and CNG vehicles—dominate the market, with conventional gasoline vehicles constituting only 30 percent of the total market by 2020. With the general reduction in congestion time, hybrids have less of an advantage under Integrated Transport than they do in the urban traffic conditions illustrated in the first two scenarios.

Congestion, parking and access difficulties, as well as the implementation of European-level fuel taxes and different transport policies, suppress the total number of cars to approximately 50 percent of what is estimated in Road Ahead in 2020. Similarly, annual distance traveled plummets to 9,000 km per vehicle by 2020 because of the high costs of driving and the extra advantages of public transport, such as bus rapid transit (BRT) and metro systems designed to give alternative high speed travel. Higher oil prices support better fuel economy together with the popularity of very small cars, which are assumed to be 25 percent gasoline and 25 percent electric by 2020.

5. SCENARIO RESULTS

5.1 Energy consumption

The Road Ahead scenario demonstrates that if car ownership and use is unconstrained, oil consumption will continue to increase rapidly as the number of automobiles increases in China. The two other scenarios offer considerably contrasting results and present important alternative outcomes led by policy options that are worth considering (Figure 4).

Energy use in each scenario is broken down by vehicle and fuel type in Figure 5. Compared to Road Ahead, energy use is 38 percent lower by 2010 and 78 percent lower by 2020 in the Integrated Transport scenario, assuming that strong transport policies and measures are implemented. Total 2020 oil use in Oil Saved is approximately 55 percent less than in Road Ahead, but it is still more than two times higher than oil use in Integrated Transport. Additionally, the total oil consumed in 2020 in the Integrated Transport scenario is only marginally higher than in 2003. This distinction, while fully a consequence of our assumptions, shows how powerful transport policies can be in leading indirectly to huge oil savings and increasing energy security.

Oil consumption comprises most of the transport energy use in Road Ahead at 450 thousand barrels per day (kbdp) in 2010 and 2,500 kbdp in 2020. Oil use in 2010 in Oil Saved is 300 kbdp and rises to 800 kbdp by 2020. In Integrated Transport, oil use is a mere 300 kbdp by 2020, 12 percent of its value in Road Ahead.
5.2 Carbon emissions

Using our input assumptions, we estimated 2003 carbon emissions from cars in China at around 8.8 million metric tons of carbon (MtC). Emissions grow to 20 MtC in 2010 and 102 MtC in 2020 in Road Ahead, assuming that no additional policies other than existing fuel economy regulations will be implemented (Figure 6). The only boundary condition for our base case is that imposed by the existing fuel economy standards. For comparison, IEA (2004a) foresees China’s transport-related CO₂ emissions at 162 MtC by 2020, up from 67 MtC in 2002. The share from cars, while small now, rises rapidly.

In the second scenario, Oil Saved, improved fuel economy, largely due to a high penetration of hybrids and restraints in the size and power of cars (aided by reduced driving distances), could reduce carbon emissions in 2020 by 50 percent (Figures 6 and 7). One of the driving forces for this decrease in carbon emissions is a shift from present fuel pricing to the Japanese or European level of fuel taxation, which would boost prices by a factor of three.

In Integrated Transport thoughtful transport policies, listed in Section 6, have a profound impact on energy use, leading to 40 percent lower carbon emissions in 2010 and 79 percent in 2020 compared to Road Ahead (Figure 7). Despite more than ten times today’s number of cars, primary energy use increases by only a factor of 2.5, only 22 percent of the level in the unconstrained case in 2020. In Integrated Transport, distance traveled per vehicle is half compared to Oil Saved. This, combined with the important share of mini-cars, reduces overall oil use and carbon emissions significantly.

6. POLICY OPTIONS

China already has a strong set of policy measures that can assist in achieving its energy security, air quality, and other goals. This section proposes additional options that will have an impact on vehicle ownership, vehicle use, infrastructure use, infrastructure access, road space use, and fuel demand, leading to increased energy efficiency, increased mobility, and reduced transport emissions. Most of these policies are implied in the assumptions underlying our scenarios in section 4, where their impacts are reflected in the scenario results in section 5. The policies assumed in the scenarios and proposed to be implemented are discussed below and include technology requirements, motor vehicle taxation, fuel taxation, road and congestion pricing policies, and public transport system improvements.

6.1 Vehicle technology requirements

As described earlier, China has already started developing its advanced and alternative-fuel vehicle technologies. For example, HEVs will be available in the market by the end of 2005. Toyota has started building its Prius hybrid sedans in China with a Chinese partner (First Automotive Works). If this effort is a success, it will lead to greater availability of HEV technology in China and could lead to more HEV production. The Government of China has the option to continue attracting and encouraging such joint efforts, and to increase the diversity of advanced vehicle technologies in China.

Fuels other than gasoline and diesel have already been used in the transport sector. The two alternative transport energy sources discussed in this chapter are CNG and electricity. It is likely that the use of natural gas for transportation will continue to increase in order to meet the growing...
need for clean transport fuel. Natural gas is now used in approximately 110,000 vehicles (mostly buses and taxis) in 12 Chinese cities (Walsh, 2003b). However, this fuel is constrained by the supply of natural gas, and the fact that it is harder to transport than oil. Therefore, despite it being a relatively clean fuel, CNG-operated vehicles might be limited to a smaller role in the transport sector, but could be used in public vehicles in polluted urban areas.

Electricity is another clean transport energy source with minimal emissions impact. It is important to note that although emissions may be produced during the production of electricity, depending on the type of electric power generation, electric vehicles are still effective when used for short travel distances, especially small electric cars used in urban cities. Since the main barrier to using electricity in motor vehicles is the storage of electricity (Walsh, 2003b), further vehicle technology development is required for greater battery storage systems.

Although most technologies are already available, China needs to create the right market for such technologies to be developed commercially. The demand for advanced and alternative-fuel vehicle technologies should also be encouraged.

### 6.2 Motor vehicle taxation

Vehicle taxation has been implemented in many developed and developing countries. When integrated into transport policies, it may lead to improved transport demand management and be a good source of revenue. Vehicle taxation may also encourage demand to shift to other transport modes. Current taxes applicable to motor vehicles in China include value added (VAT), excise, vehicle acquisition, and vehicle usage taxes (Huang, 2005). A vehicle usage tax in China is collected on an annual basis and the amount of tax paid depends on the type of vehicle. An annual tax offers more flexibility than sales tax, as tax rates can be altered over time and the burden is distributed over a longer time period for vehicle owners (Schwaab and Thielmann, 2002).

Different features might be incorporated into vehicle taxation according to different transport strategies. For instance, taxation could be implemented by vehicle type, vehicle price, vehicle size, or test emission and noise levels. A differentiated system, as applied in Sweden and Germany, offers incentives for vehicle owners to switch to low emission vehicles (IEA, 2000; Breithaupt, 2002). This is often true when vehicle taxation is differentiated according to specific emission standards, where taxes are higher on more polluting vehicles. Vehicle manufacturers may also be encouraged to develop less polluting vehicles that could be preferred by consumers due to lower taxation (Schwaab and Thielmann, 2002). However, it is important to note that vehicle taxation, unlike other taxation options, does not contribute to variable costs of transportation and therefore is unlikely to influence vehicle miles traveled or other driving habits.

Vehicle taxation would be the highest in the third scenario, Integrated Transport, as authorities reduce congestion and private motorization demand by increasing vehicle costs. In the other two scenarios—Road Ahead and Oil Saved—the ownership and use of vehicles are not taxed as substantially.
6.3 Fuel taxation

Using fuel taxation as a policy instrument can recover the variable costs of driving by charging vehicle users for transport infrastructure indirectly through individual use. Since fuel is one of the highest and most visible variable costs of vehicle use, fuel taxes encourage drivers to make more efficient use of their vehicles, reduce trip frequencies, and even switch to less fuel-intensive vehicles. Most importantly, fuel taxes help reflect the real costs of dependency on foreign oil supplies, storing oil in the event of an interruption, and other externalities.

The level of fuel taxes imposed should be enough to abate vehicle emissions and serve as revenue for transport infrastructure and maintenance purposes. The revenues collected from transport fuel are usually allocated for transport purposes, as seen in many other developed, transition, and developing countries (Carruthers, 2002). Fuel prices should include taxes to reflect the perceived externalities and risks of foreign oil imports, and fees to reflect the environmental damages related to fuel quality. The latter was the goal of fuel taxation reform in Sweden in the late 1980s and early 1990s, as taxes rose on more polluting fuels but fell on cleaner fuels (IEA, 2000).

Fuel taxes in China are virtually nonexistent at present. If fuel prices continue to remain low, energy consumption and emissions from the transport sector could follow the projections in the Road Ahead scenario. If China wants to reduce its energy consumption to levels projected in the Oil Saved and Integrated Transport scenarios, a Japanese-equivalent rate of fuel taxes should be implemented in order to encourage less oil consumption by individual consumers. An increase in fuel taxes will lead to a stronger interest for advanced vehicles and alternative fuel vehicle technologies.

6.4 Road pricing

Road pricing is another demand management strategy through which drivers pay directly for utilizing public services. Some examples are toll roads, toll bridges, and congestion pricing systems, whereby drivers are charged when entering specific zones during certain time periods. Road pricing is usually implemented by public or private highway agencies or local authorities as part of transportation demand management programs; this would be the case for China as well. Revenue collected can be used to cover investment costs of transport infrastructure and maintenance, including alternatives to cars.

These approaches can reduce overall vehicle use and shift some travel patterns to less congested times. Since fuel use per kilometer rises with congestion, congestion measures tend to slightly improve fuel economy. Experience from London, for example, shows that the imposition of a £5 fee on bringing a car into a well-defined zone during business hours led to 15 percent fewer cars entering that zone. Singapore has also achieved similar results (Menon, 2000). Given the congestion in most large Chinese cities, the implementation of such systems is an option to consider.

Charging for scarce road space is an important strategy for Chinese cities, where central areas have as little as one fifth of the space per capita compared with even more traffic congested cities such as London, Paris, and New York (Mao, 2004). The Shanghai Metropolitan Transport White Paper (People’s Government of Shanghai Municipality, 2002) discusses electronic road pricing, which is a model that Singapore has followed in its general transport strategy for the past two decades (Menon, 2000). This pricing scheme is sophisticated, as vehicles are charged on a per entry basis and could vary depending on the day, time of day, the type and size of vehicle, congestion level,
and the road and place of entry (Breithaupt, 2002). Here, public education was necessary before the implementation of the system to better inform motorists and to ensure a smooth transition.

A lesson that emerges from existing experience is that an effective road pricing system has to be designed specifically to a city’s needs and to match the local traffic conditions. Applying one city’s approach to another city without careful adaptation is risky. The Vehicle Quota System implemented in Singapore in 1990, for instance, could be applicable elsewhere but would require adaptation. This quota system determines the number of new vehicles allowed for registration, while the demand for new vehicle registrations determines the price to register. The vehicle quota for a given year is administered through the monthly release of Certificates of Entitlement, which may cost as much as a car.

Road pricing policies are extremely important in the Integrated Transport scenario, where congestion is largely avoided as a significant problem because of road pricing and other complementary measures to regulate car use. If this scenario is to be realized, it is important to announce and implement road pricing policies early, before too much investment in private automobiles and on infrastructure that is dependent on private vehicle use is made in the most congested zones. Of particular appeal for Chinese cities is the fact that with a few exceptions, private car ownership is low, hence the initial impacts will only be felt by consumers of relatively higher income levels. A major impact of the London scheme was the clearing of car traffic that otherwise slowed buses (and bicycles), even at a 20 percent reduction in car traffic. Therefore, the early imposition of congestion charging in Chinese cities would likely benefit the majority of present non-car users, as well as car users who do elect to pay car use fees.

### 6.5 Public transportation and non-motorized transport

To be an attractive alternative, a public transport system has to provide speed, convenience, comfort, and affordability. This requires policy changes and significant investment. If mass transit systems such as conventional buses, fast buses in dedicated corridors (i.e. BRT), metros, and other rail-bound systems are to compete with private cars or even motorbikes, they must improve with respect to speed and cost, as an increasing number of Chinese families will be able to afford private motor vehicles. Doing so would also deliver environmental benefits and transport efficiency benefits.

The most important and cost-effective way of promoting effective public transport systems in China is through BRT. These systems have high capacity volume, segregated bus lanes, rapid embarking and disembarking features, transit prioritization at intersections, and modal integration at bus stations and terminals. Such characteristics are appealing to passengers, and will aid in achieving sustainable urban transportation in high-population-density urban cities by reducing congestion, vehicular emissions, and by providing a cost-effective alternative transport mode.

Some of these benefits can also be attained by nonmotorized transport (NMT). Pedestrians and cyclists generate neither conventional air pollution nor CO₂. Pedestrians and cyclists are also more efficient users of scarce road space than private motor vehicles, along with being the most efficient and environmentally sustainable when making relatively short trips (Hook, 2002). In virtually every other country, however, NMT has yielded to motorized public transport and then individual vehicles. The most notable countries where NMT retains 20 percent or more share of all trips in urban areas are Denmark and the Netherlands, but the high share of NMT comes principally at the cost of bus travel and short car trips. High fuel taxes, careful urban planning, an integrated network of dedicated bike lanes, and a strong component of local commercial activities keep these alternatives to cars important.

The Government of China could continue to encourage public transport investments to enhance its quality and promote cycling and walking within urban cities. Good alternative transport modes provide options to private car ownership and use, and will limit congestion and transport pollution. This phenomenon is projected in the Integrated Transport scenario, where severe traffic congestion starts to restrict total car utilization and significant charges are added to increase the total cost of driving at the same time. In the Oil Saved scenario, the use of public transportation will also increase as higher oil prices and taxes will discourage private vehicle use. A good public transport system will hence aid in decreasing private vehicle use by being a more affordable and efficient alternative. The challenge for China is to increase the speed, reliability, and convenience of its public transportation systems before too many individuals choose to use private transport modes.
6.6 Parking charges

As urban land for parking becomes scarcer, parking charges should be increased as a measure to efficiently allocate parking spaces. Parking is free or charged at a subsidized rate in many countries (Breithaupt, 2002). However, as a demand side management measure, the costs of parking facilities or on-street parking should be distributed to motorists. Every motorist should know what it really costs to bring a car into a zone where land space is scarce. Parking charges can create substantial revenues for local municipalities and could be used for transport infrastructure maintenance.

The implementation of parking fees will increase the cost of driving in urban areas, which will make private car use less appealing. For China, this will certainly influence future patterns of car use. Congestion, as well as vehicular emissions, could decrease, especially when public transport modes are encouraged. Raising parking fees to reflect the real costs and value of space—and enforcing existing parking rules—discourages the use of cars in congested regions.

7. CONCLUSION

The trends and scenarios examined in this chapter illustrate important choices Chinese policymakers must confront. On a national level, China is in the “infancy” of personal motorization; Chinese authorities have nearly 100 years of experience to draw on from other countries on the positive and negative impacts of motorization. Given the rapidity of motorization growth in China, authorities have to act fast in order to avoid traffic safety, urban congestion, pollution, and energy problems that will increase together with continued rapid motorization. Cleaner, safer, rapid transportation systems that increase access to more people have to be developed, rather than following the narrower path of rapid individual motorization, as scenes from congested Beijing and other major Chinese cities already suggest. The sooner measures are considered, the more effective they will be. The longer policymakers wait, the more technologies, fuel choices, and travel patterns will be locked in by the fixed investments required to support them.

A key issue so far overlooked by Chinese authorities is that many motorization impacts depend not only on the emissions per kilometer, but also on the total distance driven. In the case of urban air pollution, the current focus on emissions per kilometer is proper, given the need to improve fuel quality and the enforcement of more
stringent emissions standards. If the present trends in car use continue, the huge increase in distance traveled will increase emissions significantly, hence offsetting much of the promise of improved emissions control through current air quality and emissions regulations. Thus, there are good reasons for authorities to consider strategies that will slow the rise in total distance traveled, particularly in urban cities.

Similarly, the number of motor vehicles and the total distance traveled are the key factors in determining total energy consumption and carbon emissions. Nevertheless, since the growth of motorization in China is likely to continue to increase for the next few decades, the use of advanced and alternative-fuel vehicle technologies should also reduce the externalities of motorization while meeting the demands for private car use. With the appropriate policy actions, it is also possible to have widespread use of clean, small, and efficient cars in the future, especially if car use is regulated by both restraint policies and the strategic provision of alternative transport means.

Our third scenario, Integrated Transport, is driven by a vision of an ideal future Chinese city with minimal congestion delay. Oil is a limiting concern, but not the driving factor for the results shown in this scenario. The issues that decide the quality of life in Chinese cities—including population density and size, land use, and the structure of economic and cultural activities—are far too important to be determined solely by oil markets. However, Chinese authorities may recognize that a high-oil, high-car-use model of a city in China may actually leave most Chinese with fewer choices and a lower quality of life because of the constraints of space and air pollution.

Fuel taxation and road pricing play a major role in reducing vehicle use, energy consumption, and carbon emissions in Integrated Transport. The timing of fuel taxation is crucial, as early imposition gives the automobile industry more time to adapt to its growing production capabilities to produce vehicles that capture the desired social benefits of the taxes. The earlier policies are implemented, the larger the fraction of China’s potential future drivers will have grown up under a policy with the goal of a sustainable transport system in mind. Since only a small minority of Chinese own private cars today, and most of them are from relatively well-to-do urban households, imposing fuel taxes and road pricing is likely to bring a net societal benefit. Private car users will bear the burden of increased taxes and charges, but the potential results of less driving and congestion will benefit the large majority of pedestrians, cyclists, and bus riders. The more revenue is channeled into infrastructure projects, congestion-leviating projects, and alternative transport development, the more the public will accept the imposition of relevant charges. Finally, as such changes are introduced, it would be important for Chinese local and national authorities to measure the impact of pricing policies through surveys of car and fuel use, travel time, and other impacts of the policies, as has been done in London and Singapore in connection with congestion charging.

Advanced vehicles, alternative vehicles (such as minicars), and alternative-vehicle fuel technologies already exist and could be affordable if China creates a market for these technologies. Since the transport sector, in terms of private motorization, is still relatively young compared to most other countries, China has an opportunity to truly revolutionize its auto industry and private automobile market. It is important to note, however, that even if the entire Chinese fleet of motor vehicles is transformed to advanced or alternative-fuel vehicles, the basic problems of motorization, such as heavy congestion and road traffic accidents, will still persist. Additionally, cleaner vehicles and fuels alone may not eliminate air pollution if the distance traveled per vehicle is not also reduced (Walsh, 1996).

Vehicle demand has to be optimally managed and regulated in order to reduce the adverse impacts of transportation, including energy consumption, congestion, air pollution, and ultimately GHG emissions. Advanced and alternative fuel vehicle technologies are part of the solution to reduce such adverse motorization impacts, but appropriate policy measures that could change travel patterns have to be implemented and enforced as complementary tools.
ENDNOTES

1 Further background on trends and impacts of rapid motorization in China can be found in Schipper and Ng, 2005.
2 Numerous press reports in the first third of 2005 suggest overall slowing of car sales, and a shift toward smaller, less expensive models as well. The 1,500 kilogram average should fall, at least during the present phase of market expansion. A tightening market for car loans is the principal reason for this market weakening.
3 Euro emissions standards for passenger cars and light vehicles were implemented in the European Union as early as in 1993 (Euro I) to reduce air pollution from transportation. Vehicles must meet certain exhaust emissions standards before they can be approved for sale in the European Union. The Euro IV emissions standard is currently implemented in the European Union.
4 “Activity level” includes the number of cars, the distances cars are driven, and the overall distance people travel in cars, on foot, and on all other modes, which is referred to as “modal split” as described in Schipper et al. (2002).
5 Since bus travel, particularly by BRT, would only use 10 percent as much fuel/passenger-km as car travel, the incremental oil needs for shifts to buses indicated here are small.
6 CO from “road transport” in 2002, according to IEA (2004c), was about 41 MtC. Calculations here suggest that cars constitute just over 20 percent of this figure. Trucks, buses, two-wheelers, and other motor vehicles operating on roadways are likely to constitute the large (but declining) part of transport-related emissions from China.
7 The Shanghai Metropolitan Transport White Paper is the first comprehensive transport plan for the city that outlines current and future transportation needs and sets specific objectives and actions for city planners and managers. The white paper was issued in April 2002, and is the first of its kind for any city in China. The white paper was created to respond to the transportation needs Shanghai will face as its population expands in the next 20 years and as private automobile ownership grows along with it.
8 “Private vehicles,” defined as cars and privately owned household light trucks and SUVs, numbered approximately 12 million in 2003, or 9.2 per 1000 population. The number of cars we have chosen for historical analysis is from a time series devised and used as the basis of the work in He et al. (2004).
9 In addition to the key scenario assumptions noted here, the number of cars, share of cars by each fuel type, distance driven, fuel economy, and improvement in fuel economy from hybridization are just as important. Other assumptions made in the scenarios include the availability of natural gas used for compressing gas at filling stations, the exact fuel cycle carbon emission for gasoline, natural gas, and fuels used for electric power production. These minor assumptions differ very little among the scenarios and therefore do not “cause” the variations driven by the key assumptions.

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The variables in this chapter include basic motorization factors and trends in China, estimates of car ownership, car use, and fuel economy. The number of cars in China in a given future year is the parameter with the greatest likely variation. This and other variables are projected into the future with trends derived from neighboring countries with higher income levels. Description of the assumptions include the following:

1. **Car use: distance traveled per car per year**
   The current average annual distance traveled in China is 18,000 kilometers per car, excluding taxis whose annual usage is probably well above 50,000 kilometers (Chen et al., 2005). The 18,000 average distance is swollen by the large number of government and company cars with high usage. Since the private car fleet is expected to grow much faster than the taxi or government/company fleet, average use will fall. Indeed, as the number of cars grew from low numbers in Japan or West Germany, usage per car fell slowly. This reflected both fewer people “sharing” the same car, and more truly private cars as opposed to heavily used company cars.

2. **Fuel consumption**
   For each scenario, fuel use is calculated as a product of the number of vehicles, distance traveled per car per year, and fuel per unit of distance (fuel economy), in accordance with the ASIF model of Schipper et al. (2000). With the introduction of gasoline hybrids, mini-cars, CNG vehicles, and electric vehicles, separate assumptions are made for fuel economy of each kind of vehicle. Fuel economy depends on both car weight/power and the efficiency of propulsion. We cannot separate these two variables, but we can estimate the range of fuel economy expected for a car of 3,000 kilograms (for example, a Hummer) in contrast to one weighing close to 750 kilograms (for example, a Mercedes Smart). Lying between these extremes is the average new Chinese car of 1,500 kilograms. Previous analysis (He et al., 2004) has used the road fuel economy at about 11 km/liter, or 9.1 liter/100 km. The best estimate of China’s on-road fuel economy today is 9.5 liters/100 km.

3. **Final and Primary Energy Consumption**
   Total energy use consists of the numbers of cars, distances cars traveled, and fuel economy values assumed, which will depend on the type of vehicles such as HEVs, conventional gasoline cars (including mini-cars), CNG cars, and electric cars. For electric power, the electricity per kilometer reflects what is put into the battery (Delucchi, 2005). Hence, total energy consumption (EN) is:

   \[
   EN = \sum (N_e \cdot F_{1e} \cdot D_e)
   \]

   where, \(F_{1e}\) is the fuel intensity (the inverse of fuel economy) for each car type \(e\) (in energy/km), \(N_e\) is the total number of cars of each type, and \(D_e\) is the average distance traveled by each type of car. Electricity is converted to primary energy using the figures modeled in World Energy Outlook 2004.

4. **Carbon Emissions**
   Carbon emissions are calculated for each fuel using IPCC coefficients of \(\text{CO}_2\) (converted to carbon) per unit of energy in fuel at the lower heating value. To model approximately the full fuel cycle emissions of each fuel, we have added 7 percent “overhead” to CNG and oil, and 5 percent to utility fuels. The lower figure for utility fuels reflects the fact that they are largely delivered in much greater quantities, and at least for oil, not refined as much as is gasoline delivered to vehicles. The overall results are not very sensitive to the assumed “overheads” we have added here.