

# Climate Change Mitigation Strategies for the Transportation Sector in China

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## Executive Summary

After rapid growth in motorization during the past decade, the transportation sector in China presently accounts for an estimated nine percent of the country's total CO<sub>2</sub> emissions. However, this is still well below equivalent levels in developed countries, for which the transportation sector greenhouse gas share can be above 30 percent. Current transportation trends in China, though, show that this gap is closing rapidly. As such, the Chinese transportation sector is becoming an increasingly crucial factor affecting global climate change. Developed nations are in a unique position to offer experience, advice, and support to China at this delicate moment in an effort not only to save China from environmental catastrophe, but also to address global concerns of climate change. This paper has been written in order to give foreign observers a clearer understanding of the scope of the challenges in China, and to put forward a framework for discussions on climate change mitigation strategies in the transportation sector.

China's recent, rapid economic growth has carried with it a correspondingly rapid increase in transportation demand and energy use. Between 1990 and 2004, both freight and passenger transportation activities<sup>1</sup> nearly tripled, leading to a corresponding tripling of total transportation energy consumption over the same period. In parallel, China's transportation infrastructure has also seen enormous growth; the total length of highways in China doubled between 1990 and 2004, with half of this increase occurring over 2000-2004, while the length of civil aviation routes quadrupled in the same period.

Though total volume and energy use for every motorized transportation mode in China are increasing, the growth of on-road transportation has been particularly striking. From 1990 to 2004, the total vehicle population underwent a five-fold increase, with private automobiles undergoing an increase of eighteen-fold. Despite these increases, though, overall vehicle ownership in China is still quite low; in 2004, China had on average only about nine cars per 1000 people, as compared with about 800 cars per 1000 people in the United States. However, as China's per capita GDP continues growing, so will its motorization rate. China's new car sales are projected to reach or even exceed current United States' levels by 2015-2020, with the total light duty vehicle population matching that currently in the US by 2030. As such, it is expected that on-road transportation will continue to be the dominant mode affecting transportation energy use increases.

Mitigating greenhouse gas emissions from the transportation sector requires understanding and managing China's growing transportation energy use, with specific focus on on-road transportation modes. In this paper, three overall strategies for climate change mitigation in the transportation sector are described.

The first important mitigation strategy is to reduce transportation demand by improving public transportation and introducing progressive urban transportation policies. The second strategy is to reduce energy demand from the transportation sector by improving the fuel efficiency of transportation vehicles. This can be accomplished by accelerating the adoption in China of the most fuel efficient technologies, implementing stricter fuel economy standards, and developing fiscal policies promoting improved fuel economy.

The third climate change mitigation strategy is to replace fossil-fuel based transportation sector energy sources with alternative and renewable energy sources, such as

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<sup>1</sup> Often measured as passenger-km for passenger transportation and ton-km for freight transportation

ethanol or bio-diesel, which will result in significant net reductions in greenhouse gas emissions. However, both considerable research on the economic and technical viability of these energy sources and technologies within China, as well as appropriate governmental policy support, are still required.

Many other countries have already and are currently engaged in similar research efforts directed at improving the fuel efficiency of and decreasing the greenhouse gas emissions from their transportation sectors. However, different countries and regions have adopted very different strategies and priorities; for example, Brazil has adopted ethanol as a primary alternative energy source due to that country's abundant sugar cane supply, Japan is strongly supporting the development and use of light-weight and hybrid vehicles, while the European Union is pushing dieselization and bio-diesel through aggressive fuel economy and alternative fuel targets. When discussing climate change in China, it is important to engage the international community to help understand these international precedents and focus on identifying which long-term climate change mitigation strategies will prove most effective under challenging and unique Chinese conditions.

Finally, when discussing statistics on the transportation sector in China, it is important to recognize the profound limitations on available data. The pace at which China has developed, coupled with the lack of sufficient funding, organization, and resources for research groups and government bodies, as well as a lack of transparency and openness, has resulted in a shortage of accurate and reliable data regarding transportation energy use and greenhouse gas emissions from the transportation sector. Therefore, in parallel with undertaking the mitigation strategies, one of the first and most immediate tasks in China is to improve China's research and data collection abilities to understand better the energy demands and greenhouse gas inventory from the transportation sector.

## Introduction

This report presents a brief summary of key Chinese transportation policies, statistics, historical trends, and projections for the purpose of facilitating dialogue on climate change mitigation strategies for the transportation sector in China. This report is divided into three sections. In the first section, background data on the current state of transportation and transportation energy use in China is presented. The second section focuses on the current state of Chinese on-road transportation, which forms the largest component of energy consumption in the transportation sector and is the greatest source of concern for rising greenhouse gas emissions. The third and final section of the report introduces key climate change mitigation strategies for the transportation sector in China. This section is divided up into general transportation demand management strategies, strategies to improve fuel efficiency, and strategies to replace fossil-fuel-based transportation energy sources with alternative and renewable fuels.

In November, 2004, the National Development and Reform Commission in China published the “China Medium and Long Term Energy Conservation Plan,” outlining general priorities in the area of fuel efficiency across many sectors. With regard to the transportation sector, the document lists qualitative energy objectives, including developing China’s diesel automobile industry, continuing to develop fuel economy standards and developing fuel taxes, accelerating development of public transportation, especially road public transport, and continuing to develop less energy-intensive technologies for non-road transportation modes. China’s 11<sup>th</sup> Five Year Plan lists similar objectives, and also includes encouraging the development of environmentally friendly, renewable, alternative fuels, especially for use in the transportation sector.

The Chinese government’s primary goal of these objectives is not reducing greenhouse gas emissions, but rather reducing China’s dependence on foreign oil in order to improve energy security. However, inherent in many energy security strategies are climate change mitigation opportunities. Therefore, as China moves forward towards a more energy-secure future, it is important to understand and prioritize climate change mitigation as a parallel goal.

## Part 1: General Transportation Energy Use

### 1.1 Transportation Use, Infrastructure, and Energy Consumption

Transportation demand and use has grown dramatically in China in recent years. Figure 1 shows the past 15 years' growth of freight and passenger activities in China. Both nearly tripled over the period 1990-2004. Passenger activities (measured in passenger-km) increased 280% from about 560 billion passenger-km to over 1.6 trillion passenger-km. Over the same period, freight activities (measured in ton-km) increased over 260% from 2.6 trillion ton-km to nearly 7 trillion ton-km.

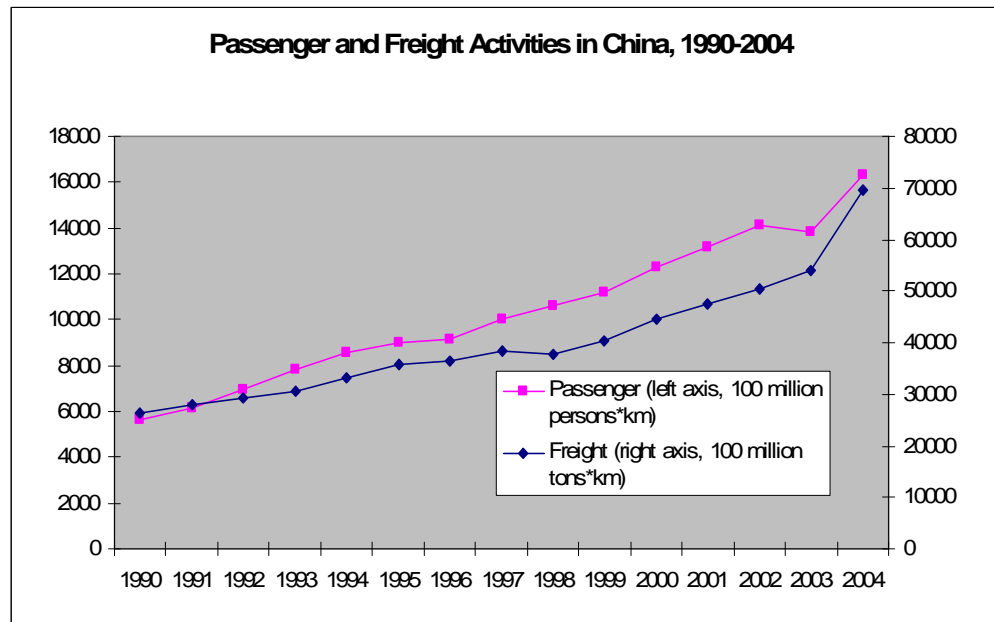


Figure 1: Passenger and freight activities in China, 1990-2004 (1990-1996 data from MOC, 1997-2004 data from CATARC, CAAM, 2005).

Transportation infrastructure has also increased significantly, particularly in the lengths of highway and civil aviation routes. Figures 2 and 3 show the absolute increases in transportation infrastructure across various transportation modes.

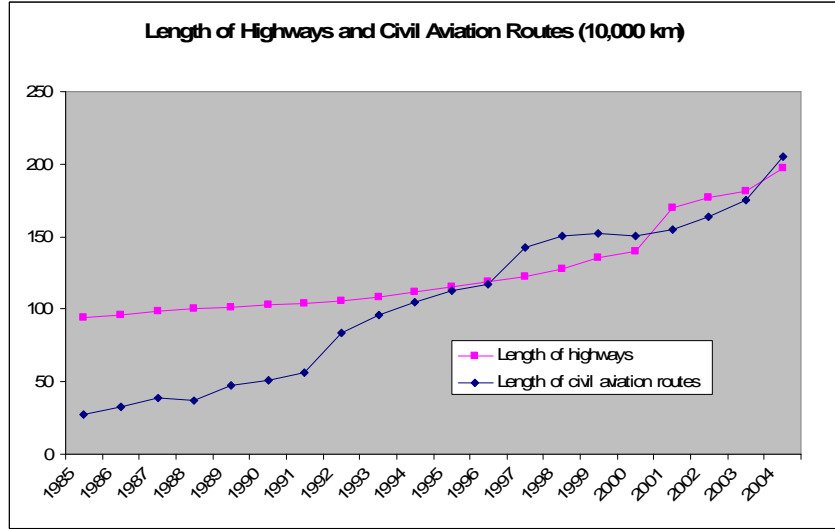


Figure 2: Lengths of Chinese highways and civil aviation routes, 1985-2004 (CATARC, CAAM, 2005).

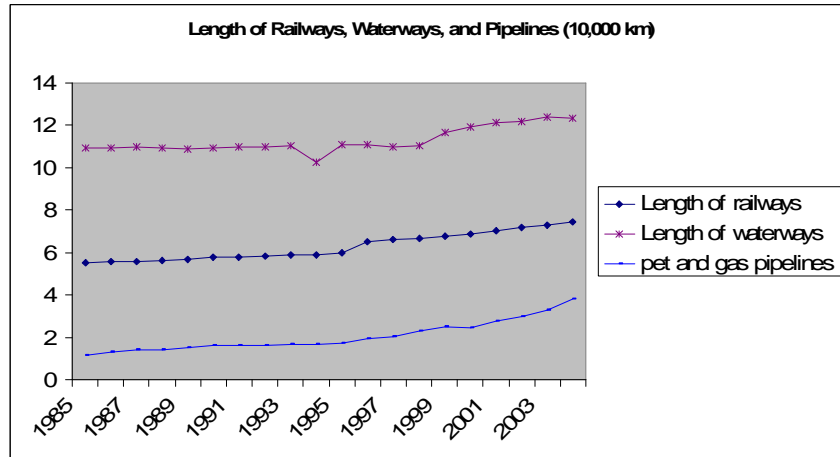


Figure 3: Lengths of other transportation infrastructures, 1985-2004 (CATARC, CAAM, 2005).

In Figure 2, note especially the dramatic increases in highways; highway lengths increased from approximately 100,000 kilometers in 1990 to over 200,000 kilometers in 2004. 50,000 kilometers of this increase happened over the period 2000-2004 alone.

In parallel with growing transportation demand and infrastructure, transportation energy use has also grown. However, reliable and accurate data on overall energy consumption by the transportation sector in China is not readily available. Officially, the Chinese National Bureau of Statistics publishes sector-based energy consumption data, though transportation is only included in a single “Transport, Storage, and Post” sector. This data, shown in Figure 4, shows approximately a tripling of energy used by this sector, from 45 million tons standard coal equivalent (SCE) to 127 million tons SCE, over the period 1990-2003.

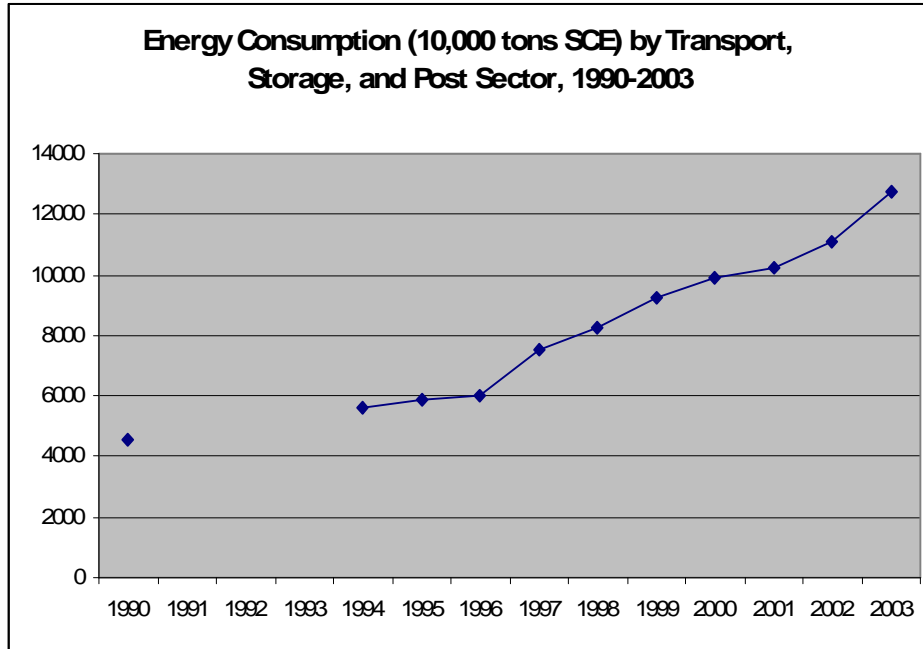


Figure 4: Energy consumption by transport, storage, and post sector, 1990-2003 (NBS, 2005).

The Chinese National Bureau of Statistics also publishes total energy consumption across all sectors. Based on these numbers, Figure 5 shows energy share of the transportation sector as a percentage of the total energy use over time. Note again that this data includes post and storage sectors.

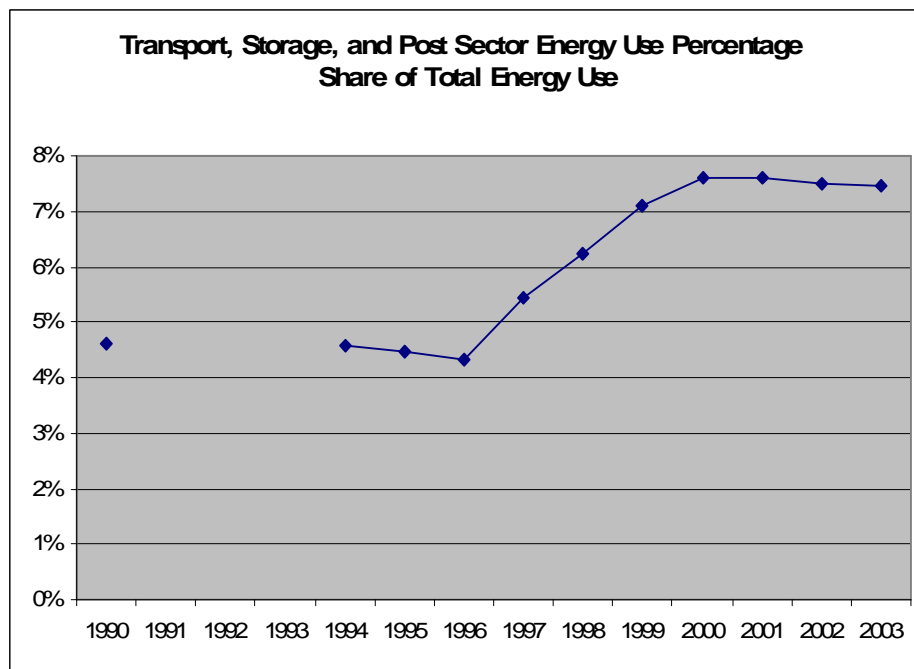


Figure 5: Transport, storage, and post sector energy use share (NBS, 2005).

The data shown in Figure 5 shows that the transport, storage, and post sector currently comprises less than 8% of the total energy used by the country. It should be noted, though, that the data shown in Figures 4 and 5 is official data from the Chinese government, and is somewhat out of synch with transportation energy data from other external research groups. This is because the Chinese government transportation data only covers transport-related commercial energy use, not all energy use from transportation activities.

For comparison, the Energy Information Agency’s 2005 International Energy Outlook showed a transportation energy use share in 2002 in China of 9.41%, approximately two percentage points higher than the official Chinese data (EIA, 2005). The Asia Pacific Energy Research Center cites that this discrepancy may be even as high as six percentage points, and is increasing over time (APERC, 2004). Clearly, researching and understanding the actual energy use by the transportation sector, especially as this differs from what the Chinese government reports, is one important area for future work in China.

Even accounting for the discrepancy between Chinese government data and external research data, it seems clear that the current energy use share by the transportation sector in China is still well below that of developed nations. In 2004, the transportation energy use share of the United States was approximately 27% of total primary energy consumption (EIA, 2005), while that of the UK was approximately 29% (IEA).

As China further develops, it is expected that the transportation energy share will increase. Table 1 presents projections by several research groups for future transportation energy share percentage in China:

Organization	Source	Year	Transportation Energy Share Projection
Energy Information Agency	EIA, 2005	2025	14%
Asia Pacific Energy Research Center	APERC, 2004	2020	16%
International Energy Agency	World Energy Outlook 2002, cited in APERC, 2004	2030	23%
Tsinghua University	Guo Baolei, 2003, cited in APERC, 2004	2030	20%

*Table 1: Summary of various transportation energy share projections.*

The driving force behind this increase in transportation energy consumption share is the explosion of the on-road vehicle population. This growth is discussed in Part 2 of this report.

### *1.2 Transportation CO<sub>2</sub> Emissions Estimate*

In 2004, the Chinese government published the “Initial National Communication on Climate Change,” a comprehensive summary of energy use and greenhouse gas emissions across all sectors in China, including the transportation sector. However, this document only covered data through 1994. Though an update through 2004 is in development, it has not yet reached press. As such, the Chinese government is currently not able to provide detailed data regarding transportation sector greenhouse gas emissions.

However, the Energy Research Institute of the National Development and Reform Commission in China was able to provide one estimate of 352 million tons of CO<sub>2</sub> for the total emissions from the transportation sector in 2004 (Zhu, 2006). According to the EIA,

China's total CO<sub>2</sub> emissions in 2003 were 3.54 billion tons (EIA, 2005). As the increase in China's total energy consumption was 15.1% in 2003-2004 (BP, 2005), China's total 2004 CO<sub>2</sub> emissions may be estimated at 4076 million tons. Therefore, the percentage of total CO<sub>2</sub> released by the transportation sector in 2004 is estimated to be 8.6% of the total CO<sub>2</sub> released in China. This is in line with previous estimates for total energy consumption share percentage by the transportation sector.

## Part 2: On-Road Transportation

### 2.1 Current On-Road Transportation Summary

Within the transportation sector, the largest consumer of energy is on-road transportation. Even more importantly, the percentage share of energy used by on-road transportation out of total transportation energy consumed is rising dramatically. Table 2 shows this increasing energy consumption and consumption share of energy use for highway transportation.

Transport Mode:	Energy Consumption			Consumption Share		
	1990	2000	Ratio	1990	2000	Change
Railways	14,851 ktoe	13,017 ktoe	0.88	27.8 %	13.5 %	-14.2 %
Highways	25,495 ktoe	65,516 ktoe	2.57	47.6 %	68.1 %	+20.5 %
Waterways	11,407 ktoe	11,988 ktoe	1.05	21.3 %	12.5 %	-8.8 %
Civil Aviation	1,222 ktoe	5,090 ktoe	4.16	2.3 %	5.3 %	+3.0 %
Pipelines	550 ktoe	605 ktoe	1.10	1.0 %	0.6 %	-0.4 %
Total	53,524 ktoe	96,214 ktoe	1.80	100.0 %	100.0 %	0.0 %

Table 2: Energy consumption and consumption share by transportation mode, 1990 and 2000 (APEREC, 2004).

Table 2 shows that in 2000, transportation on highways accounted for 68.1% of the energy consumed in the transportation sector, up from 47.6% in 1990. Since 2000, this consumption share has almost certainly increased, as the increase is being driven by an exploding vehicle population in China. This exploding vehicle population may be seen in Figure 6, showing recent annual vehicle sales in China, and Figure 7, showing recent overall in-use automobile population.

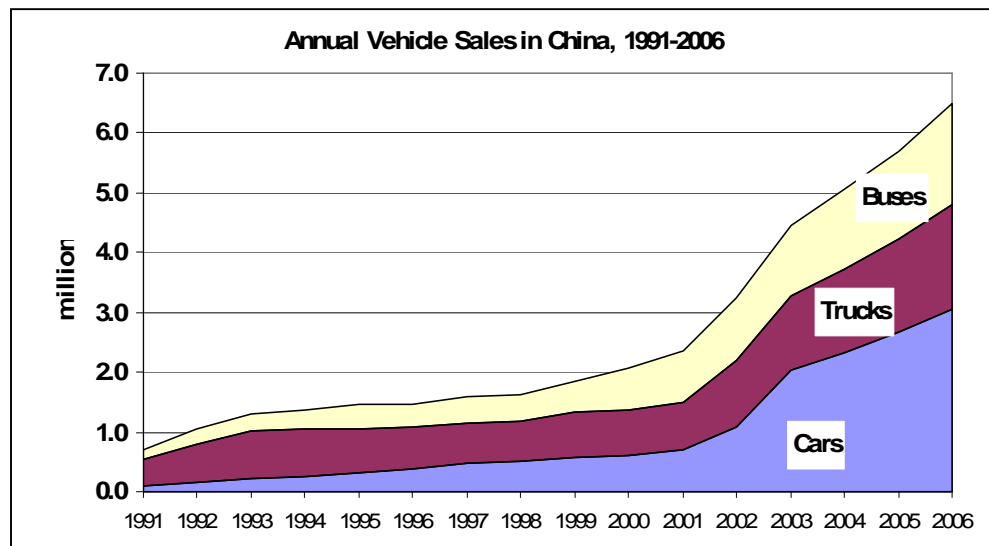


Figure 6: Annual vehicle sales in China, 1991-2006 (An, 2006).

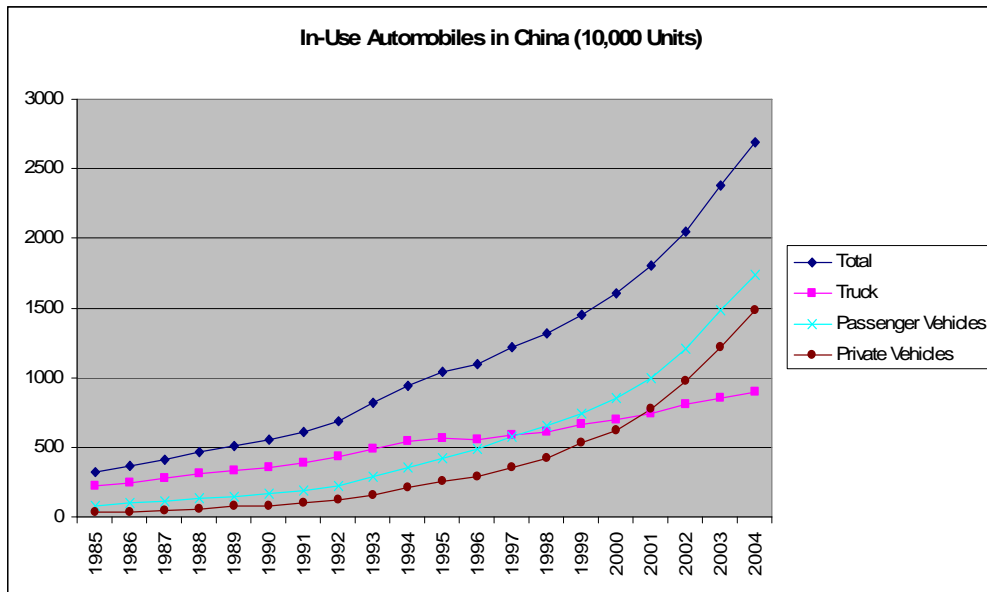


Figure 7: In-use automobiles in China, 1985-2004 (CATARC, CAAM, 2005).

In Figures 6 and 7, note especially the dramatic increase in car sales (five-fold increase from 1999-2005) and use of private vehicles (eighteen-fold increase from 1990-2004). Because of these numbers, China is on track to become the second largest vehicle market in the world in 2006, with new vehicle sales approaching 6.5 million units per year.

Despite the significant recent increases in passenger vehicle sales, however, per capita vehicle ownership in China is still low; in 2004, China had only about nine cars per 1000 people, as compared with about 800 cars per 1000 people in the United States (WRI, 2005). Figure 8 shows a comparison of car ownership vs. per capita GDP for China as compared with other developed nations. As China's per capita GDP rises, car ownership will certainly increase as well, following similar trends.

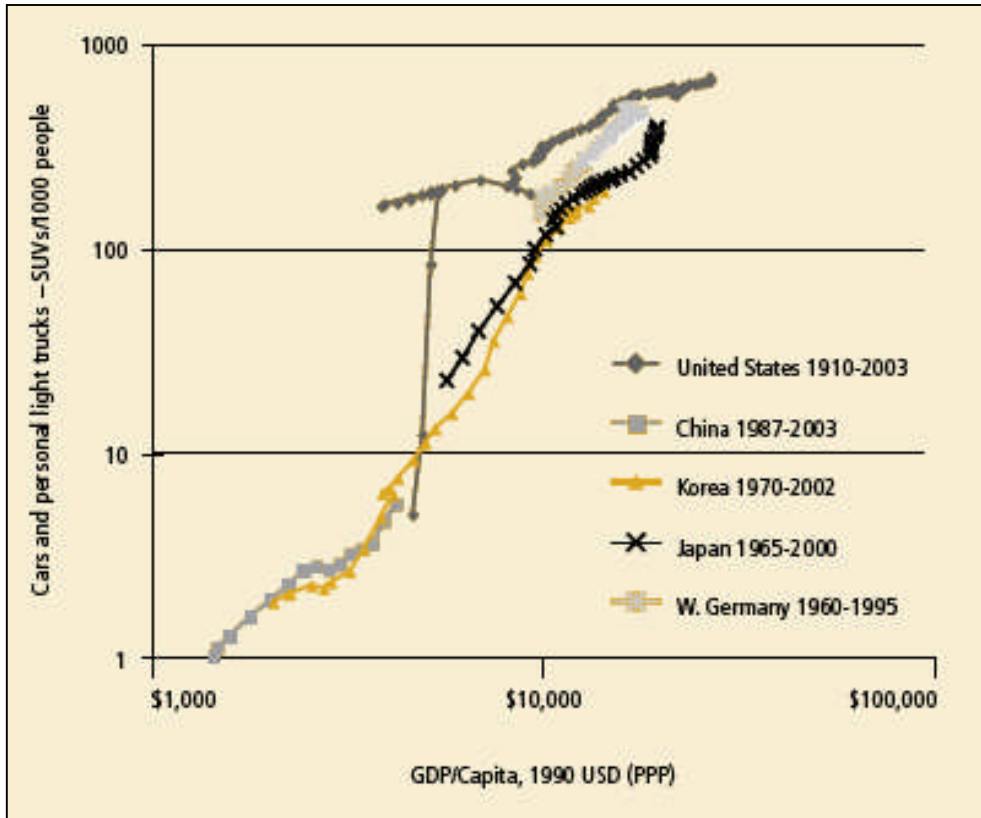


Figure 8: Comparison of historical trends in car ownership vs. GDP for several countries (WRI, 2005).

Though private, passenger vehicle ownership is rising, the current population of vehicles in China is still dominated by motorcycles and rural vehicles. Figure 9 shows vehicle population and shares in China in 2003. The data shows car, bus, and truck populations each in the 7-8 million range, whereas the motorcycle population was nearly 60 million (one per twenty people) and the rural vehicle population was above 22 million.

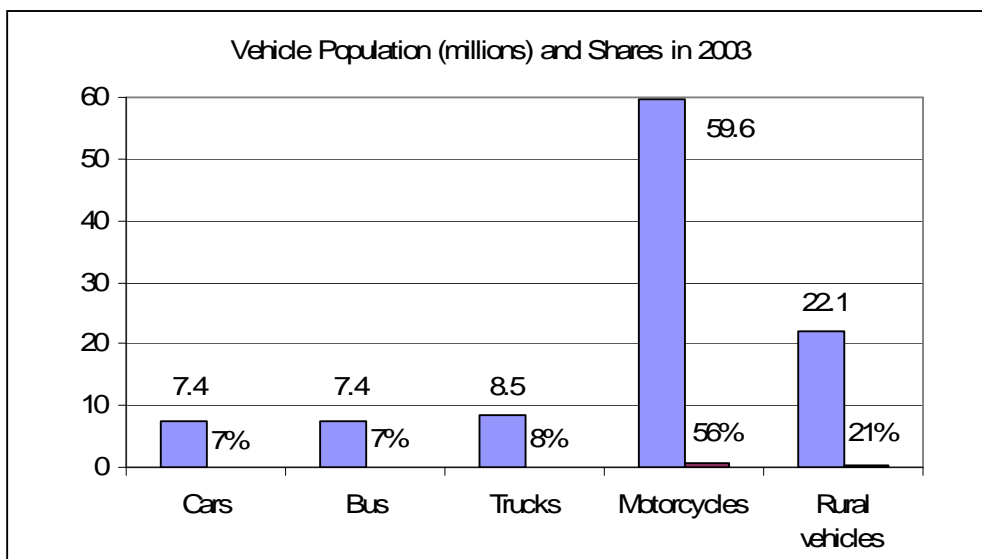


Figure 9: Vehicle population and shares in 2003 (An, 2006).

Based on fleet fuel economy and vehicle distance traveled estimates, Figure 10 presents an estimation of the fuel consumption (in million metric tons, MMT) and shares of the Chinese vehicle population in 2003 (An, 2006; He, 2005).

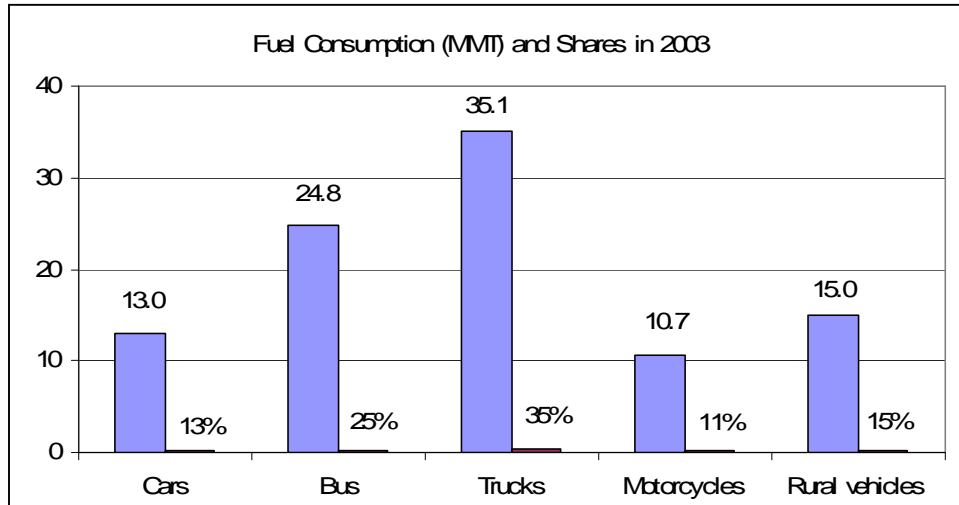


Figure 10: Vehicle fuel consumption by type, 2003 (An, 2006).

With regard to rural vehicles, the estimate in Figure 10 shows an energy consumption rate of 15% of the total transportation energy use. This rural vehicle energy use is not well documented by the Chinese government (possibly included in data on the agricultural sector as opposed to the transportation sector), and is an important area for further research (Sperling, 2003).

The two primary fuels currently used for vehicle transportation in China are gasoline and diesel. Gasoline is primarily used by cars and motorcycles, whereas diesel is primarily used in buses, trucks, and exclusively in rural vehicles. Though several cities in China currently have programs to convert buses and taxis to run on compressed natural gas (CNG), this use still comprises a very small percentage of total fuel consumption by this sector. (CNG developments are discussed further in Part 3 of this report.) Figure 11 shows recent trends of gasoline and diesel consumption in China. Over the period 1990-2004, gasoline consumption by automobiles increased nearly 230% from 20 million tons in 1990 to 45 million tons in 2004, while diesel consumption by automobiles increased 530% from just 5 million tons in 1990 to 24 million tons in 2004.

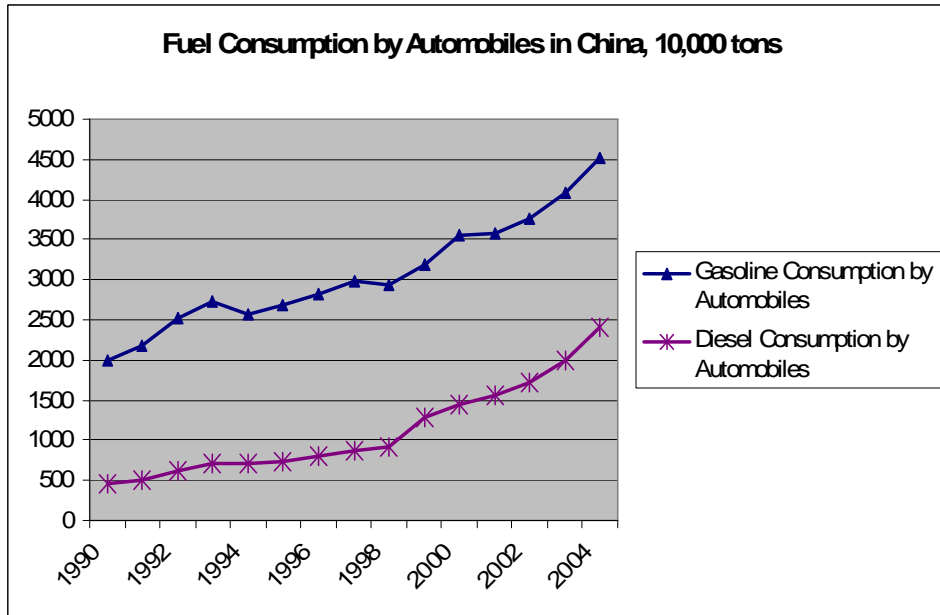


Figure 11: Fuel consumption by automobiles in China, 1990-2004 (CATARC, CAAM, 2005).

## 2.2 On-Road Transportation, Oil-Use, and CO<sub>2</sub> Emissions Projections

Experts agree that the on-road vehicle population in China will continue its rapid growth. Figure 12 presents one projection of annual light duty vehicle sales in China (An, 2006). By this estimation, annual sales are projected to reach United States' levels as early as 2015.

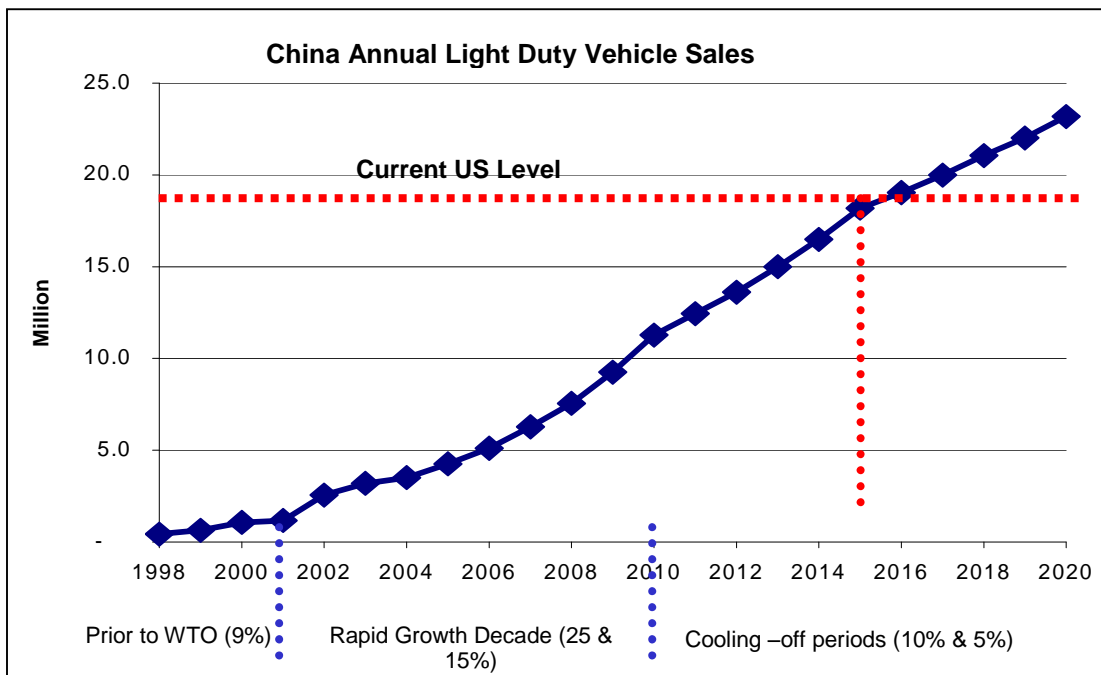


Figure 12: China annual light duty vehicle sales projections (An, 2006).

With sales increasing dramatically, so will the overall vehicle population, shown in Figure 13. This projection shows China's total vehicle population approaching the current US level of 200 million by approximately 2030.

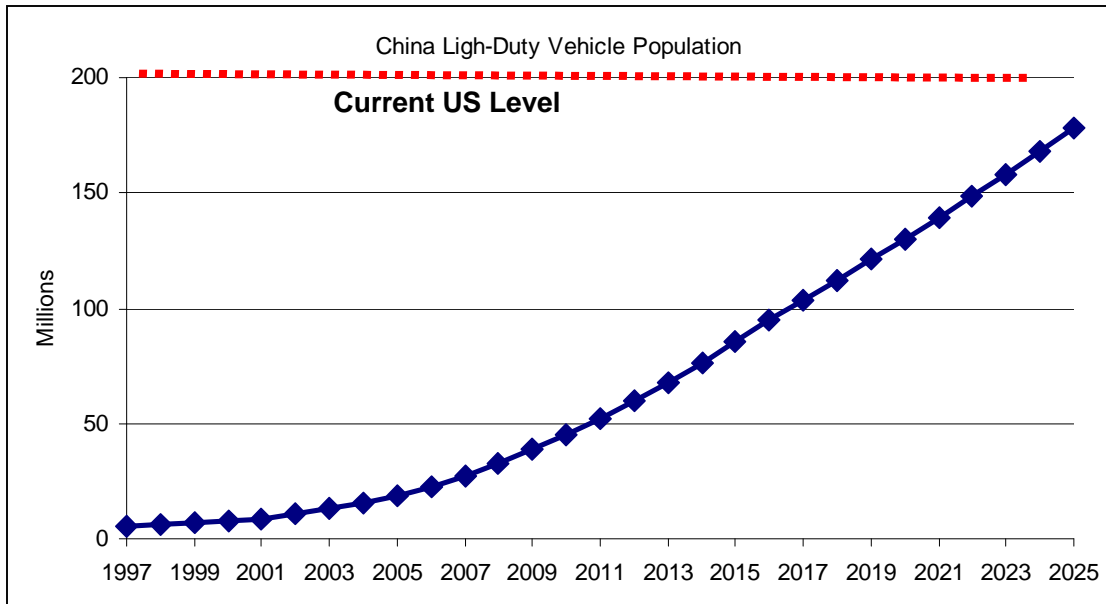


Figure 13: China annual light duty vehicle population projection (An, 2006).

Figures 14 and 15 show on-road oil consumption and greenhouse gas emissions projections for the next 20 years. The projections are presented based on two scenarios: 1) a business-as-usual (BAU) scenario based on the projections of on-road vehicle population growth shown in Figure 13; and 2) the current governmental projection assuming steady 6% annual growth. While both scenarios demonstrate rapid increases in oil consumption and GHG emissions from on-road transportation, they also demonstrate a wide range of uncertainties in future projection. Under these two scenarios, the oil consumption and GHG emission projections from the BAU case is nearly double that of the 6% scenario in 2030.

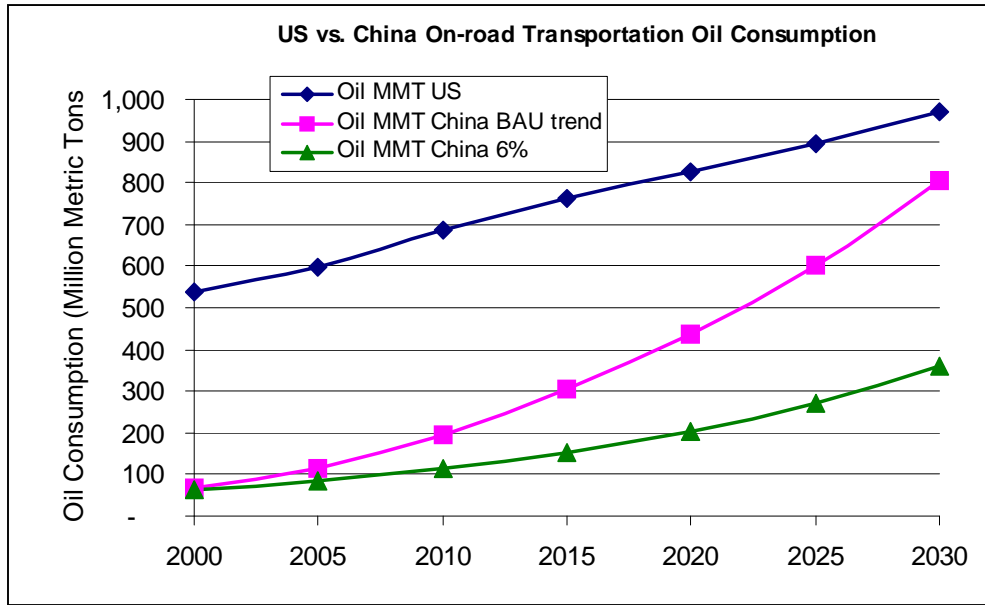


Figure 14: On-road transportation oil consumption projection (An, 2006).

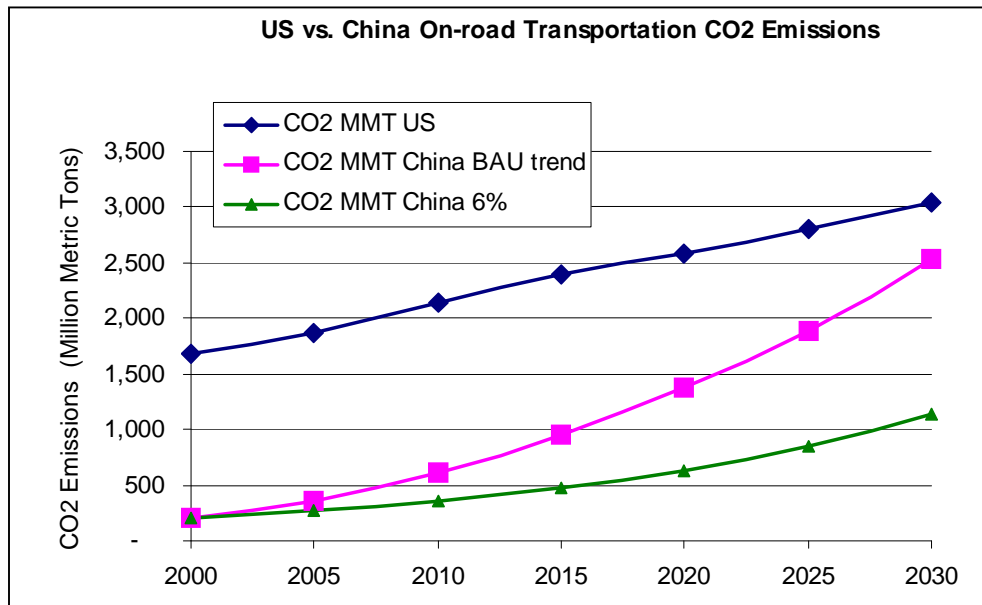


Figure 15: On-road transportation CO<sub>2</sub> emissions projection (An, 2006).

### 2.3 On-road Oil Consumption in the Context of China's Overall Oil Demand

Figure 16 shows China's net oil production and consumption from 1975 to 2004. Ever since China became a net oil importer in 1993, the gap between production and consumption has been steadily widening.

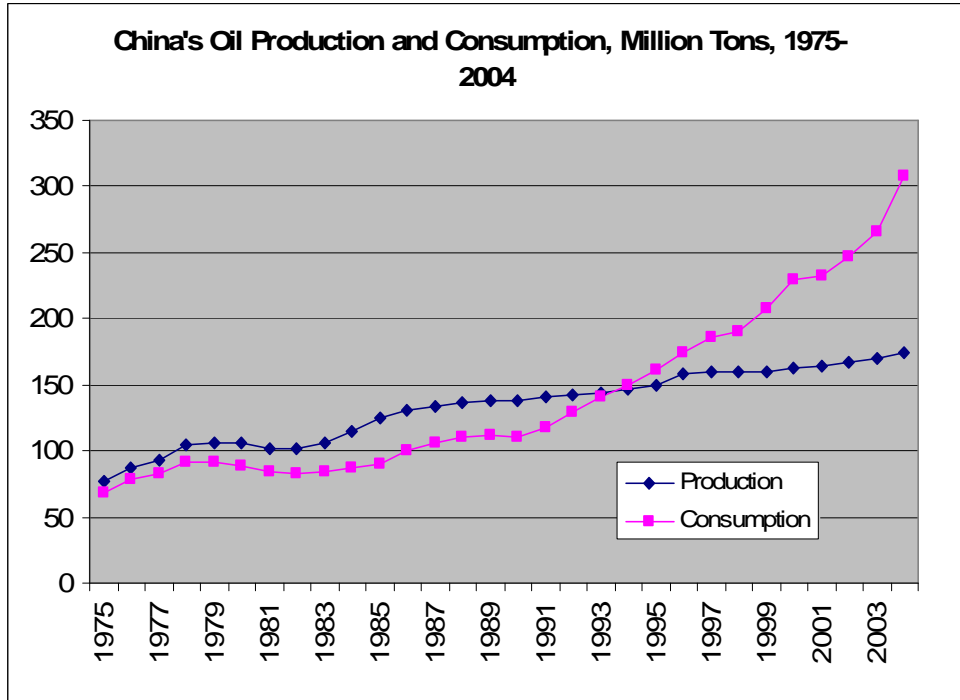


Figure 16: China's oil production and consumption, 1975-2004 (BP, 2005).

The International Energy Association's World Energy Outlook, shown in Figure 17, shows this percentage of imported oil continuing to rise over the next few decades, possibly reaching above 70% in 2030.

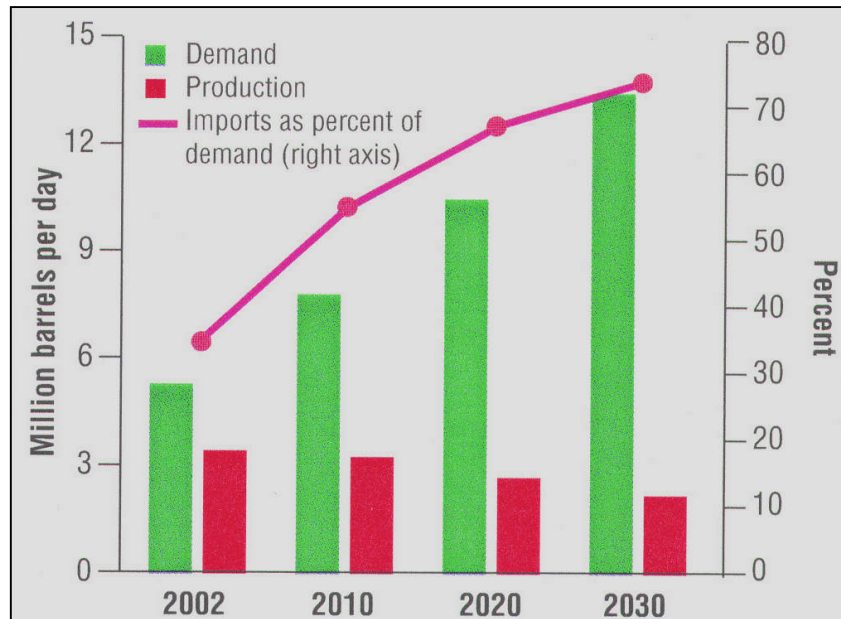


Figure 17: China overall oil demand and import projections to 2030 (IEA, 2004, cited in An, 2006).

Figures 16 and 17 highlight that China is facing an energy security crisis due to its growing dependence on imported petroleum. In 2004, the transportation sector used

approximately 25% of imported oil in China (CBO, 2004). The Chinese government is fully aware that, with transportation energy use rising, implementing strategies and policies for this sector now are crucial in controlling overall energy security for the country. As mentioned in the introduction, energy security and climate change mitigation strategies are frequently parallel. The remainder of this report describes some current and potential policy and technology options to reduce or replace energy sources for the transportation sector with secure and more environmentally friendly options.

## Part 3: Climate Change Mitigation Strategies

This section of the report presents possible strategies and policies through which total transportation energy demand and greenhouse gas emissions (with specific focus on on-road vehicles) can be controlled and reduced. With per capita vehicle ownership rates in China still relatively low, now is an important and critical time to implement fuel and greenhouse gas saving strategies to steer Chinese automotive and transportation trends in a more sustainable direction.

Three basic categories of strategies are presented in this section:

- 1) Transportation demand management (TDM) strategies and policies, focusing on encouraging the use of less energy-intensive forms of transportation. These include promoting public transportation, encouraging people to drive less, and developing effective sustainable urban planning to minimize transportation needs.
- 2) Strategies and policies to reduce greenhouse gas emissions from the automotive sector by improving the energy efficiency of the vehicle fleet. This includes discussion of fiscal policies encouraging people to buy and use more efficient vehicles, policies to promote in China advanced and more fuel efficient vehicle technologies, and vehicle fuel economy standards.
- 3) Strategies and policies to replace transportation energy sources in China with greenhouse gas minimizing alternative or renewable fuels, such as bio-fuels.

Many of the policies and strategies presented in this section have been researched and developed in other countries. Not all of these strategies, however, are applicable to Chinese conditions. As mentioned in previous sections, it is imperative that research efforts on the appropriateness of implementing various climate change mitigation strategies be conducted before large-scale investment and policy implementation begins.

### *3.1 Transportation Demand Management (TDM)*

China's rapidly motorizing population carries a host of negative externalities besides additional greenhouse gas emissions. These effects include increased air pollution, traffic congestion, and traffic-related injuries. Transportation experts in the global community as well as within China agree that engaging in system-level transportation demand management (TDM) in Chinese cities is a crucial overall step in controlling not only transportation energy demand and greenhouse gas emissions, but also other associated negative effects. General TDM strategies and policies aim to encourage the use of more energy efficient public transportation modes and to discourage the use of personal vehicles. Presented here are some of these TDM strategies and policies.

Because reducing urban congestion depends more on specific attributes of city land use and transport systems than on vehicles, most countries assign responsibility for congestion management to local or metropolitan governments. Such management includes traffic enforcement, parking control, and local charges for registration and vehicle use that may affect vehicle ownership.

Motorization in urban areas also has an impact on land use patterns. The growth of trucks and motorized freight encourages firms to move out from the center of urban areas. The corresponding decentralization of employment encourages the suburbanization of

residential development as workers follow jobs (Ingram, 1998), as well as providing opportunities for city workers to live increasingly distant from the city center. These locational changes reduce central city population densities and produce dispersed travel patterns that are less easily served by public transit. In cities, motor vehicle use promotes motor vehicle dependence because the locational residential changes and infrastructure investments made are difficult to reverse. Nascent tendencies in this direction are evident in several large Chinese cities that are experiencing falling central population densities, growth in suburban employment, and the emergence of auto-dependent households living in metropolitan suburbs.

There is currently a widespread, misguided philosophy behind urban planning in Chinese cities that the purpose of transportation planning is to increase relentlessly **mobility**, as measured in traffic volume of motor vehicles. A more progressive and sustainable urban planning philosophy should focus on improving **accessibility** for all citizens and transportation modes, especially for transit and non-motorized travel modes.

### **Public Transportation**

The International Association of Public Transport states that public transport can be up to an order of magnitude more energy efficient than personal automobile use (UTIP-EU, 2006). To reduce vehicle ownership and energy consumption by a rapidly urbanizing population, China must provide in its cities fast, efficient, convenient, and economical public transportation including subway or other mass rapid transit, buses, light rail, and bus rapid transit (BRT). As personal incomes rise and personal motor vehicles become more affordable, one great challenge for China is how to maintain the currently high use of public transportation.

As municipal governments face the challenge of providing public transportation to an urban population, it is important to consider the construction and operating costs, environmental impacts, energy consumption and greenhouse gas emissions, and of course the effectiveness as a transportation tool in terms of comfort, speed, reliability, and expandability. Generally, subways are the most ideal public transport tool because they are fast, efficient, and clean. However, subway tunneling and construction represent an enormous cost which only a few of China's wealthiest cities have been able to afford up to the present time.

Bus networks are a cheaper alternative and are already widely used in China. BRT specifically is emerging as an important and cost-effective method of promoting effective public transportation in China, because BRT systems have relatively low capital investment and high capacity volumes. The main features of a BRT system are dedicated bus lanes with timed lights for continuous, rapid transit along with designated stations with ticketing and boarding similar to a subway system. BRT has been particularly successful in Latin American cities, and China is actively engaged in duplicating that success with BRT currently running in Beijing and Kunming and additional lines under development in 14 other cities (CAI, 2006).

### **Fiscal Policies**

Fiscal policies, including vehicle and fuel taxes as well as road and parking pricing schemes, are an important way both to affect manufacturer and consumer behavior and to generate revenue to invest in transportation infrastructure. Generally, vehicle taxes and fees

can be divided into three different categories: excise taxes on manufacturers or consumers, fuel taxes, and utilization taxes and fees on consumers.

### *Vehicle Manufacturing and Sales Taxes*

Currently in China, fuel efficiency is taken into account by fiscal policy in the excise tax levied on the manufacturers. These taxes range from 3-20% of sale price and are based on engine size in an effort to encourage the production of smaller, more efficient vehicles. According to recent reforms enacted April 1, 2006, cars with an engine displacement greater than 2.0 liters are taxed at much higher rates, up to 20% for the highest category, while cars with displacements between 1.5 and 2.0 liters are taxed at 5%, and cars with displacements less than 1.5 liters are taxed at just 3%. A summary of these tax rates is shown in Table 3. In similar efforts, China has also recently revised its exception policy for SUVs, which until recently enjoyed a special excise tax rate of 5% (An, 2006). SUVs are now taxed by engine size along with other passenger vehicles.

<b>Vehicle Category by Engine Displacement</b>	<b>Tax Rate</b>
<b>Automobiles</b>	
1.0 to 1.5 liters	3%
1.5 to 2.0 liters	5%
2.0 to 2.5 liters	9%
2.5 to 3.0 liters	12%
3.0 to 4.0 liters	15%
4.0+ liters	20%
<b>Commercial Buses</b>	5%
<b>Motorcycles</b>	
<250cc	3%
>250cc	10%

*Table 3: Vehicle manufacturing excise tax rates in china (MOF, 2006).*

Sales tax levied on consumers is currently 10% of the sale price, with no differentiation by engine size. One current reform proposal to this scheme is to transfer the engine size tax from being on the manufacturer to being on the consumer. This would provide better transparency between the consumer's price and the fuel efficiency of the vehicle and presumably influence the choice of more a fuel efficient vehicle.

### *Fuel Taxes*

In stark contrast to policies in many developed countries, China does not presently have a fuel tax to take into account the environmental externalities and energy security concerns of the consumption of oil. Fuel taxation is extremely effective at limiting vehicle use and encouraging the use of fuel-efficient vehicles, as it is the highest and most visible variable cost incurred during vehicle use. Additionally, taxing fuel is the most direct method of taxing consumption and, for fossil-fuel based fuels, CO<sub>2</sub> or carbon emissions. Current fuel taxes around the world range from around 20c/liter in the United States to 50-70c/liter in Europe and Japan. Proposals for fuel tax systems have been under discussion for years within the Chinese government. These proposals mainly focus on reforming the current

“fee based” revenue system to a “fuel tax-based” revenue system. Such proposals have been stalled in large part by the political difficulty in allocating revenues among different governmental agencies, as well as rivalries between provincial and central governments.

### *Other In-Use Fees*

In-use vehicle fees include road and parking pricing schemes to restrict the use of personal vehicles. Road pricing includes the use of toll roads, toll bridges, and congestion pricing systems penalizing drivers for using specific zones at specific times (e.g. daily fees imposed on drivers in London’s city center). Since fuel use per kilometer traveled rises slightly with congestion, measures to alleviate traffic congestion also tend to increase fuel economy. China’s cities could potentially benefit greatly from congestion pricing systems or even no-car zones or no-car days. These policy options would also encourage the use of public transport, walking, and bicycles in congested areas. This may be an important opportunity for China to take advantage of while car ownership is still low.

### **Other Policy Support**

International experience has shown a host of other policy strategies designed to discourage the use of private vehicles and / or encourage the use of more fuel efficient vehicles and transportation modes. For example, in the United States, some States have enacted special lanes for use only by high-occupancy vehicles and fuel-efficient vehicles like hybrids. Other areas have specific restrictions, for example, Paris has banned the use of SUVs within certain inner city areas. Though China has yet to implement any of these types of policies, the government is working to eliminate past policies moving in the opposite direction. Specifically, China just this year lifted an existing ban on small cars in cities.

Land use controls and planning are also another option used to reduce the use of private motor vehicles. These policies include the restriction and pricing of parking spaces, the use of pedestrian zones and parks, and land use zoning strategies which need to be carefully integrated into a public transport system. For example, it has been found in many large cities that limiting the supply of inner city parking spaces can be effective at reducing traffic congestion and encouraging the use of public transport. Other examples are Hong Kong island closing off several of its central downtown streets to vehicles on weekends to create pedestrian zones, and the placement of residential zones in the city center.

Another China policy currently under development is a first-ever National Environmentally-Friendly Vehicle (EFV) Rating system. The system, designed to measure the total environmental impact of various vehicle models, gives an overall “Green Score” to each vehicle model based on its tailpipe pollutant emissions, tailpipe CO<sub>2</sub> emissions, and weight. The system is designed to give manufacturers, consumers, and policy-makers a metric by which to measure the total environmental impact of different vehicle models. As the system becomes finalized, there is hope that the scoring system may become the base of future policies such as criteria for green procurement of government vehicles and the application of subsidies or tax-breaks.

The green scores for all vehicles in China will ultimately be made available on a searchable online database. Additionally, the Chinese State Environmental Protection Administration is currently developing a vehicle environmental label to be displayed on all cars participating in the EFV rating system. The label will include information on green score, fuel economy, and emissions, and will give transparency to the consumers of the

environmental impact of their vehicle choice. In Switzerland, a fuel economy label implemented in 2003 showed immediate improvements, including a 1.5% decrease in new vehicle average CO<sub>2</sub> emissions in just the second year of the program (Niederburger and Brunner, 2006).

The need for vehicle labeling also stems from the fact that general consciousness of environmental impacts of vehicles is low in China. Public education and information are powerful and important tools to sway the vehicle market by creating mental connections between environmental externalities and particular sizes, kinds, or models of vehicle.

### *3.2 Fuel Efficiency Improvement Policies*

#### **Fuel Economy Standards**

In October, 2004, the Chinese government implemented the first-ever fuel economy standards for new passenger vehicles in China. Though these standards are primarily designed to help mitigate China's increasing dependence on foreign oil, other objectives include encouraging foreign auto manufacturers to bring state-of-the-art vehicle technologies to the Chinese market and squeezing out small and less-competent indigenous manufacturers.

The current fuel economy standards become effective in two phases. Phase I went into effect in July, 2005, for new type models and in July, 2006, for continued models. Phase II goes into effect in January, 2008, for new type models and January, 2009, for existing models. The standards apply to passenger cars, SUVs, and MPVs with less than nine seats. Within the system, vehicles are divided up by transmission type (except SUVs and MPVs with 3+ rows, for which there is no differentiation by transmission type), and weight. The 16 weight classes are identical to those used by the EU for emissions categories. Within each class, each vehicle model must meet a maximum fuel consumption standard in l/100-km when tested using the New European Drive Cycle.

One distinctive feature of the Chinese standards is that, rather than being based on fleet average, they set up maximum allowable fuel consumption limits by weight category. Every individual vehicle model sold in China is required to meet the standard for its weight class. Unlike other fuel economy regulatory systems, the Chinese system does not include a credit system to allow vehicles that exceed compliance to offset those that do not.

The current fuel economy standards in China are summarized in Table 4. The standards were designed to be "bottom heavy," meaning that they become relatively more stringent in the heavier vehicle classes than in the lighter weight classes. This will help to create incentives for manufacturers to produce lighter vehicles for the Chinese market.

Weight (lbs)	Maximum fuel consumption limits, based on NEDC cycle (L/100-km)			
	Phase I [2005]		Phase II [2008]	
	Manual	Auto/SUV	Manual	Auto/SUV
≤1,667	7.2	7.6	6.2	6.6
≤1,922	7.2	7.6	6.5	6.9
≤2,178	7.7	8.2	7.0	7.4
≤2,422	8.3	8.8	7.5	8.0
≤2,678	8.9	9.4	8.1	8.6
≤2,933	9.5	10.1	8.6	9.1
≤3,178	10.1	10.7	9.2	9.8
≤3,422	10.7	11.3	9.7	10.3
≤3,689	11.3	12.0	10.2	10.8
≤3,933	11.9	12.6	10.7	11.3
≤4,178	12.4	13.1	11.1	11.8
≤4,444	12.8	13.6	11.5	12.2
≤4689	13.2	14.0	11.9	12.6
≤5066	13.7	14.5	12.3	13.0
≤5578	14.6	15.5	13.1	13.9
> 5578	15.5	16.4	13.9	14.7

*Table 4: Current fuel economy standards in China (An, 2006).*

A recent report for the Pew Center on Global Climate Change (An and Sauer, 2004) compared automobile fuel economy and GHG standards for nine different countries and regions around the world. The standards vary greatly from country to country, and are therefore difficult to compare directly. In the report, An and Sauer researched and collected vehicle fuel economy data and developed a methodology to solve this problem. Figure 18 presents their comparison of China's new vehicle fleet average fuel economy standards with international ones as a result of corresponding fuel economy regulations. The graph shows US CAFE-equivalent fuel economy ratings in miles per gallon (mpg) versus implementation years for corresponding vehicle standards. Dashed lines represent proposed standards.

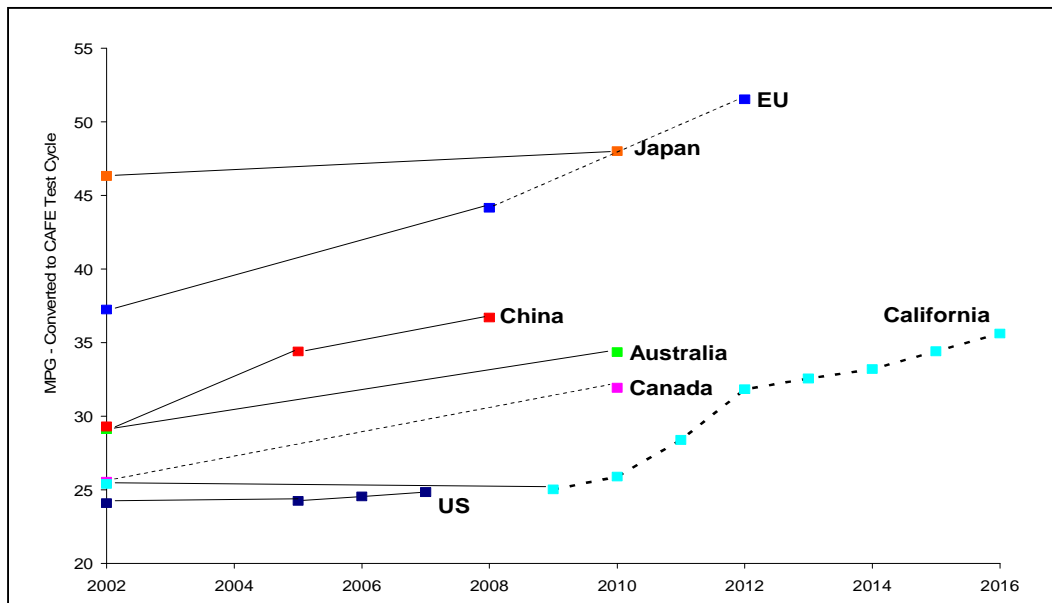


Figure 18: Comparison of international current and future fuel economy standards for passenger vehicles (An and Sauer, 2004).

Figure 18 shows that China’s current fuel economy standards are better than those in many other international regions. However, two caveats to this table must be mentioned. The first caveat is that the current level of fuel efficiency of the Chinese vehicle fleet is not well known, and thus the relative stringency and effect of these standards is not well understood. Since these standards only apply to new vehicles, the fuel-efficiency of pre-2004 vehicles and the total vehicle population is uncertain. The second caveat is that commercial vehicles and pickup trucks are not regulated under the standards. Fuel economy standards for light duty commercial vehicles are currently in development, and are expected to be published sometime in the next two years. Developing additional fuel economy standards, for example for heavy duty commercial vehicles, should also be ultimately implemented.

The diversity of international standards shown in Figure 18 highlights the need for international collaboration to develop harmonized vehicle standards for all markets. This international harmonization will ultimately accelerate the adoption in all developing nations of the latest technologies, and is important both for fuel economy and vehicle emissions. International discussion is imperative to agree on these harmonized standards such that developing nations do not become siphons for out-dated, environmentally-unfriendly vehicles and technologies when better ones exist.

With regard to vehicle fuel economy standards in general, there has been concern about the so-called “rebound effect” which theorizes that by improving fuel economy of vehicles, consumers will be inadvertently encouraged to drive more and thus offset the benefits of fuel savings promised by improved efficiency. However, empirical research has shown that this is a small secondary effect with minimum impacts. Various studies usually put the impacts of rebound effects between zero to ten percent of the fuel savings.

The fiscal policies described in the previous section as well as the fuel economy standards described here are important steps in encouraging the manufacture and use of more fuel-efficient vehicles in the Chinese market. Most, if not all of these strategies, have

some international precedent. Table 5, first presented in An and Sauer's report, presents an overall summary of international precedent in the promotion of more fuel-efficient vehicles.

**Measures to promote fuel-efficient vehicles around the world**

<i>Fuel efficiency approach</i>	<i>Measures/forms</i>	<i>Country/region</i>
Fuel economy standards	Numeric standard in mpg, km/L, or L/100-km	United States, Japan, Canada, Australia, China, Taiwan, South Korea
GHG emission standards	Grams/km or grams/mile	European Union, California
High fuel taxes	Fuel taxes at least 50% greater than crude oil base price	European Union, Japan
Fiscal incentives	Tax relief based on engine size, efficiency, and carbon dioxide emissions	European Union, Japan
R&D programs	Incentives for particular technologies and alternative fuels	United States, Japan, European Union
Economic penalties	Gas guzzler tax	United States
Technology mandates and targets	Sales requirement for ZEVs	California
Traffic control measures	Hybrids allowed in HOV lanes; ban on SUVs	Several U.S. States (hybrid HOV lanes); Paris (SUV ban)

Note: This list is not exhaustive.

*Table 5: Measures to promote fuel-efficient vehicles around the world (An and Sauer, 2004).*

The final sections of this report discuss technology and policy options related to the introduction in China of significantly energy saving vehicles and fuels.

### **Advanced Fuel Efficient Vehicle Technologies**

The overall fuel efficiency of the vehicle population in China could be greatly improved by introducing or expanding the use of advanced fuel efficient vehicle technologies in China. However, at the present time, domestic and multinational automotive manufacturers in China are still in the process of bringing their standard car models up to international standards of low emissions and high fuel efficiency. Therefore, though many advanced fuel efficient technologies do have international precedent, China-based manufacturers in most cases currently do not possess the technical ability to produce these advanced vehicles.

Chinese infrastructure and fiscal policy support are needed both to bring international best practice to China and to encourage China-based manufacturers to develop their own advanced technology. In both cases, there are opportunities for international companies in many auto-related industries including imports/exports, engineering development, manufacturing, consulting, and financing.

In parallel, China must work to promote and further develop enabling policies which encourage and allow this international investment and local development. Such policies include continuing to tighten fuel economy standards, implementing research and development fiscal support, and developing policies encouraging and allowing foreign investment in the areas of advanced vehicle technology. Another option is for China to

consider taxing CO<sub>2</sub> or carbon emissions directly, as opposed to engine size as they do now. This would directly promote advanced vehicle technologies and fuels which decrease greenhouse gas emissions.

The following section of the report presents an overview of some alternative technology options for the transportation sector in China. These options are:

- 1) Hybrid Electric Vehicles (HEVs)
- 2) Diesel Engines
- 3) Mini-cars
- 4) Electric-drive Vehicles (including battery electric vehicles (BEVs), plug-in hybrids and Fuel Cell Vehicles (FCVs))

In each case, a brief description of the technology is presented, followed by a discussion of international experience and applicability to China.

#### *Hybrid Electric Vehicles (HEVs)*

A hybrid-electric vehicle (HEV) combines an electric drive with a down-sized internal combustion engine. HEVs consume less energy by regenerating energy while braking, using smaller engines, allowing the engine to run at its optimal efficiency through computer control, and allowing the engine to be turned off during stops, braking, and coasting. Depending on driving conditions and specifics of hybrid technologies, HEVs can achieve fuel efficiency gains of 25% or higher than comparable, gasoline-powered vehicles.

HEVs have been targeted especially in the United States and Japan as important technologies to improve the fuel efficiency of the current vehicle fleet. Hybrid vehicle technology, as well as economic and policy support for its development, is becoming more mature worldwide; therefore, many experts think HEVs can and will develop quickly in China.

Current HEV penetration in the world auto market, however, is not large, primarily due to the relatively high cost of the technology. In the United States, an HEV costs approximately \$3-5000 more than a comparable, conventionally powered vehicle; even when factoring in future fuel savings, the overall cost of ownership of an HEV is still generally higher than for gasoline powered vehicles.

As HEV manufacturing matures, it is expected that the cost will decrease. Until that point, though, two important strategies are required to push HEV development in China. First, because HEVs become more cost-effective as vehicle mileage increases due to decreased fuel consumption, HEVs are ideally suited initially for high mileage applications such as in taxis and buses. Shanghai is currently running a pilot program with hybrid taxis and buses; such pilot programs must be continued and furthered in other areas of the country to research HEV appropriateness and savings in public transportation settings.

Second, China must work in the near-term to develop fiscal incentives to encourage the development and purchasing of hybrid vehicles. Such fiscal incentives have been implemented in the United States, for example, subsidies for hybrid cars (or tax exemptions) and fuel taxes to emphasize the benefit of fuel savings.

### *Diesel Vehicles*

Direct-injection lean-burn diesel engines generally offer an approximate 20-25% efficiency gain when compared to a similar gasoline engine. However, diesel engines are inherently more polluting, particularly for the criteria pollutants  $\text{NO}_x$  and  $\text{PM}_{10}$ . Therefore, while pushing widespread diesel use can improve vehicle fleet energy efficiency, it can also lead to greater air pollution, especially in congested urban areas. Though technologies do exist for retrofitting diesel engines to decrease the criteria pollutant emissions, these technologies are more expensive and generally require the use of clean, low-sulfur diesel fuel.

For this reason, there has been a marked split in dieselization implementation in developed countries. Specifically, the EU has pushed diesel adoption aggressively through allowing higher emissions standards for diesel engines and providing diesel fuel subsidies. The EU hopes that dieselizing its vehicle fleet will help it meet specific vehicle fleet average  $\text{CO}_2$  emission targets. In contrast, the United States and Japan have taken strides to keep diesel market penetration low (choosing, instead, to push hybrid technology and efficient gasoline engines). Diesel cars presently account for over 50% of new car sales in Europe. In comparison, this technology is used in only a few percent of car sales in the Japanese or US markets (Cheng, 2006).

While diesel fuel is a primary fuel used in off-road and commercial transportation in China, there are still essentially no passenger diesel cars in China. However, the National Development and Reform Commission is currently actively researching and evaluating whether dieselizing China's passenger vehicle fleet is an appropriate strategy. The primary concerns regarding dieselization in China are as follows:

- 1) Diesel fuel quality in China is still extremely low, with sulfur levels at about 500ppm in Beijing and Shanghai and approaching 2000ppm in many regions of China (as compared with 15ppm in the US and 50ppm in the EU). The current, high sulfur level in Chinese diesel fuel prohibits implementation of diesel engine pollution control catalyst technology to reduce  $\text{NO}_x$  and  $\text{PM}_{10}$  emission levels. If China is going to push diesel fuel within the passenger vehicle fleet, controlling air pollution will require developing corresponding ability to refine and transport low-sulfur fuel. This will require significant infrastructure investment.
- 2) Even if China does invest in required infrastructure to create high quality diesel, there is still some concern regarding China's diesel fuel production and availability.

### *Mini-cars*

Mini-cars generally weigh less than 800kg and have an engine displacement below 800cc. As such, they are ideal for space-constrained and energy conscious urban settings. Typical fuel efficiencies achieved by mini-cars are approximately 40-60mpg (WRI, 2005), on par with current HEV technologies. However, mini-cars carry with them none of the increased cost of the HEV technology and therefore, from a price perspective, are likely to penetrate the Chinese market more easily than HEVs.

One primary reason mini-cars have not gained significant headway into developed automobile markets is that, in areas where the per capita automobile ownership rate is already high, expectations about how a car should look and feel are already highly developed. Perceptions on vehicle safety have also suppressed the use of mini-cars in developed countries. In China, however, where many people still have no vehicle expectations, there

may be better opportunities to push mini-cars though these efforts have failed in other countries.

### *Electric-drive Vehicles, including pure battery BEVs, and Fuel Cell Vehicles (FCVs).*

Using electricity as a transportation energy source means that emissions per kilometer traveled are related only to the emissions produced at electricity generating power plants. Electric vehicles tend to have lower overall primary energy requirements per kilometer than gasoline cars of the same size, depending on primary energy sources (WRI, 2005). Additionally, their lower speeds and performance mean they will not be driven as much or as fast as conventional gasoline cars, thus indirectly contributing to energy savings.

However, current, purely electric vehicle are generally only suitable for traveling short distances due to limitations on energy storage (battery) capacity. In China's eleventh five-year plan, electric vehicles are one of the research areas pinpointed for development. Universities, research institutes, and car manufactures are encouraged to carry out pilot projects and in-depth researches. This research includes not only opportunities for four-wheeled EVs, but also electric powered bicycles.

Fuel Cell Vehicles (FCVs) are electric vehicles whose electricity power source comes from a hydrogen fuel cell. Although a large amount of effort has gone into research and development of fuel-cell vehicles in developed countries, there are still important technical hurdles to be overcome including a cheap and reliable source of hydrogen fuel, the safe and convenient on-board storage of hydrogen gas, and the creation of a hydrogen re-fueling infrastructure. The only current experience China has with FCVs are in a few pilot programs underway to develop fuel cell buses in China.

### *3.3 Alternative Fuels*

Whereas the previous two sections described strategies and policies to reduce total transportation energy demand and improve the fuel efficiency of the vehicle fleet, this section presents alternative fuels which can replace petroleum-based fossil-fuels as the feed-stock used for on-road transportation and reduce net carbon dioxide emissions. Three alternative fuels are discussed:

- 1) Compressed Natural Gas (CNG)
- 2) Ethanol
- 3) Bio-diesel

#### *Compressed Natural Gas (CNG)*

CNG as a transportation fuel is appealing because it is a more efficient fuel than gasoline, is less carbon intensive, and burns much cleaner. Estimates of the performance of CNG vehicles are a 25% reduction in carbon dioxide, 90-97% reduction in carbon monoxide, and 35-60% reduction in nitrogen dioxide as compared to a gasoline equivalent (WRI, 2005). In China, CNG is currently used to power about 110,000 public vehicles, mainly buses and taxis, in about 11 major cities (WRI, 2005).

Though CNG is a favorable alternative fuel to improve air pollution and reduce greenhouse gas emissions in major urban areas, it is unlikely that CNG will ultimately be a

major alternative source of energy in the transportation sector in China because China's limited CNG supply and reserves do not justify the investment required to convert China's transportation fleet to CNG-compatible engines and develop the associated delivery infrastructure.

### *Ethanol*

Ethanol is an alternative energy source created from sugar or carbohydrate vegetable stocks, most often sugar cane or corn, and is being pushed aggressively in Brazil and, to a lesser extent, the United States. Ethanol is a gasoline substitute and may be blended with conventional gasoline up to about 10% without required engine modifications for the existing, gasoline-powered fleet.

In Brazil, ethanol accounts for as much as 20% of fuel use, though Brazil is a unique case in which ethanol development has been supported both by strong feedstock supply from sugar cane as well as tremendous government support in the form of technology mandates and fiscal policies. In parallel with Brazil's ethanol production increase, Brazil's auto market has seen an explosion of flex-fuel vehicles which are designed to run on any blend of ethanol and gasoline. This has resulted in approximately seven out of 10 cars being sold in Brazil being flex-fuel vehicles (Luhnnow and Samor, 2006). Ultimately, this gives the consumer the choice at the pump of filling his or her vehicle with the cheapest fuel.

In the United States, ethanol is mainly produced from corn, and is more expensive than Brazilian sugar cane ethanol due to lower crop yields. However, ethanol is still touted as a primary future source of alternative energy for the US. Additionally, the US provides incentives for manufacturers creating flex-fuel vehicles in the form of credits given to these vehicles when evaluating fleet average fuel economy for CAFE requirements.

In China, ethanol production from corn is approximately 2 million tons per year with production supported by a subsidy of about 2000 RMB/ton (Zhu, 2006). This is the only alternative fuel to be supported currently by Chinese fiscal policies. This subsidy is aimed at helping reduce dependence on foreign oil; however, ethanol production is currently displacing crop land and effects on food security are constraining further expansion.

### *Bio-Diesel*

Bio-diesel is a generic name given to any diesel fuel created from high lipid-content biomass and designed to function in existing diesel engines. Bio-diesel is different from ethanol in that it can be produced not only from virgin crop feedstocks, but also from waste oil and grease. Bio-diesel is estimated to reduce greenhouse gas emissions by as much as 90% as compared to regular diesel (GTZ, 2006). Depending on quality, bio-diesel can be blended with regular diesel in amounts ranging up to 20% without requiring engine modifications.

Though ethanol is the only bio-fuel currently supported by fiscal subsidies in China, a bio-diesel subsidy is expected by the end of the year and there is significant research and development going into China's bio-diesel industry. Currently, China's bio-diesel production and capacity, shown in Figure 19, are quite small.

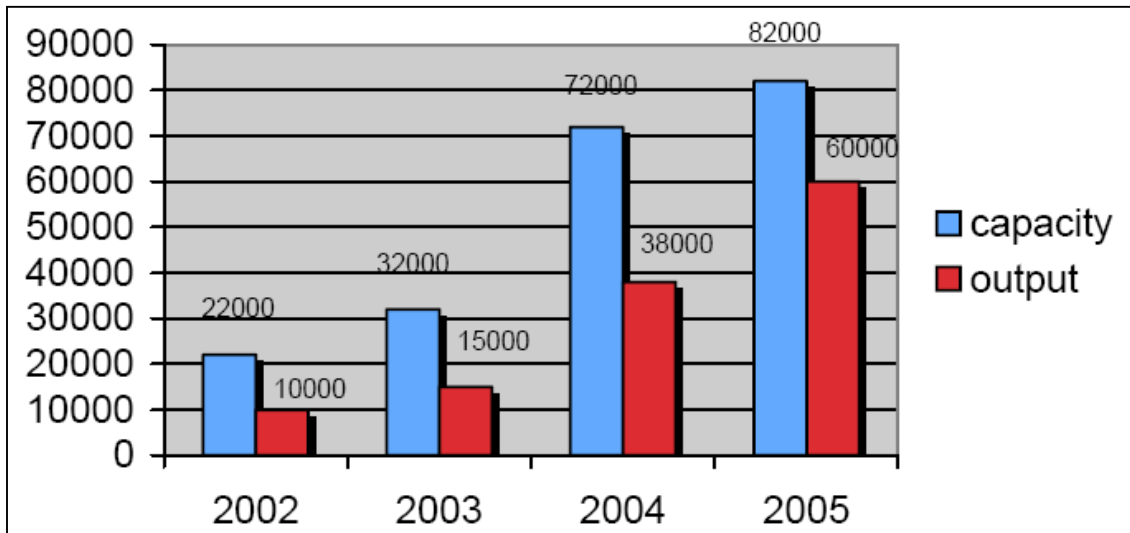


Figure 19: China's recent bio-diesel capacity and output in tons/year

By the end of 2006, though, it is estimated that there will be 40 plants in China producing about 200,000 tons/year of bio-diesel, mostly from waste oil (Wen, 2006). This production is still well below the potential for waste oil recovery which is estimated in China to be approximately 2 million tons of bio-diesel per year from a total annual waste oil feedstock of 3 million tons.

However, experts agree that waste oil alone will not be sufficient to satisfy China's bio-diesel demand. Theoretically, the bio-diesel market in China is as large as the blending ratio times the standard diesel market. If blended at 5-20%, the bio-diesel market in China could currently be 5-20 million tons / year (Wen, 2006). Of course, this market would be expanded greatly if government support for diesel vehicles were implemented. Additionally, with extremely aggressive alternative diesel fuel requirements in Europe, there is the possibility that a mature Chinese bio-diesel market could eventually export bio-diesel to Europe.

Bio-diesel is an area that is ripe for international investment, especially by EU companies that have existing technical experience. However, for China's bio-diesel industry to thrive, experts agree that significant policy support from the Chinese government will be required. This policy support required includes, but is not limited to:

- Subsidies to facilitate planting of crops and production of bio-diesel as opposed to other food crops. Ideally, more energy efficient fuels such as diesel could be priced below gasoline.
- Regulations to enforce the collection and recycling of waste-oil for bio-diesel.
- Policies to control the fuel quality of bio-diesel so as to help facilitate widespread standardization and adoption.
- Policies to control the fuel market such that overall diesel market penetration in China can grow.

Lastly, it is thought that strong bio-diesel investment in rural areas can help with another goal of the Chinese government, that of better distributing wealth across all provinces.

*Summary of Alternative Vehicle Technology and Fuel Options*

Table 6 presents a summary of the advanced, fuel efficient vehicle technologies and alternative fuels presented in this paper.

<b>Technology / Fuel</b>	<b>Advantages</b>	<b>Disadvantages</b>	<b>GHG / Energy Savings</b>	<b>Chinese Supporting Policies Required</b>	<b>International Investment Opportunities</b>
<b>Hybrid Electric Vehicles</b>	Technology mature, precedent in US, Japan	Increased cost	> 25% improvement over gasoline	Fiscal policies to reduce cost, green procurement policies, mandates or targets for market penetration	Assistance to Chinese manufacturers to develop local capacity and technology, manufacturing improvements to bring cost down
<b>Diesel Engines</b>	Technology mature, strong precedent in EU	Increased pollution, requires significant investment to create low sulfur diesel in China, diesel supply in China is limited	20-25% improvement over gasoline	Subsidies to promote diesel fuel, develop ultra low-sulfur diesel (ULSD) fuel	Engine retrofit solutions for pollution control, investment in refining for low-sulfur diesel
<b>Mini-cars</b>	Technology mature, cheaper, can help alleviate congestion	Contrasts with traditional image of passenger car, concerns about safety	30% improvement over standard-size vehicles	Market mandates, green procurement policies, traffic or parking policies to encourage urban use	Bringing existing models and technology to Chinese market
<b>Electric Vehicles</b>	Significant urban air pollution improvement	Increase cost, concerns about battery life, short driving range	Depends on efficiency of power plant, probably significant	Similar to mini-cars plus technical mandates and support	Bringing existing models and technology to Chinese market, transferring technology to Chinese manufacturers, assisting in technical development
<b>Fuel Cell Vehicles</b>	Significant urban air pollution improvement	Increased cost, technology far from mature, supporting infrastructure required	Significant potential, but will depend on the source of hydrogen fuel	Research and development investment, continued pilot studies	Research and development, technology transfer
<b>CNG</b>	Air pollution improvement, some GHG savings	Cost required to convert vehicles and develop delivery infrastructure, limited supply	Up to 25%	Fiscal policies to convert engines, green procurement policies	Engine retrofitting
<b>Ethanol</b>	Air pollution improvement, improved energy security, precedent in Brazil, US	Limits on blending unless vehicles are converted, concerns regarding food security	Depends on feedstock and blending ratio, can be 30-70%	Some subsidies exist already, need further assistance to alleviate food security concerns, alternative fuel mandates	Technology development, capacity development, consulting
<b>Bio-diesel</b>	Air pollution improvement, promotes energy security, precedent in EU, waste grease and oil can be recaptured	Concerns about food security, requires blending with limited petroleum based diesel supply	Depends on feedstock and blending ratio, can be 30-90%	Subsidies, fuel quality standards, alternative fuel mandates, ultimately may require passenger vehicle dieselization	Technology development, capacity development, consulting

*Table 6: Summary of alternative vehicle technology and fuel options for China.*

## Conclusions

It is clear that China's transportation energy demands, especially for on-road transportation, will increase dramatically in the coming years. It is also clear that the share of energy used by the transportation sector will continue to grow compared to other energy demands from industry, electricity generation, and buildings.

China is currently facing a number of important choices with regard to how to mitigate the emissions of greenhouse gases from this rapidly growing transportation sector. After a brief overview of developments in the transportation sector, this paper presented brief descriptions of the main climate change mitigation strategy options in this sector in China. Some options, such as encouraging public transportation and developing policies and standards to improve fuel economy, are definite, important strategies, and, although implementation has successfully begun in China, there is still ample opportunity for them to be taken further. Other options, such as the use of hybrid electric vehicles, diesel vehicles or bio-fuels, are more difficult to assess, especially against a back-drop of conflicting international examples, complex local conditions, and significant initial investments. However, the sooner they can be analyzed and developed, the more effective a role they can play at combating climate change. Perhaps the biggest uncertainty in China's climate change mitigation future is whether the country will follow the EU in pushing diesel (and bio-diesel) as a primary transportation fuel source, or whether China will follow the United States in pushing gasoline, ethanol, and hybrid vehicles. The future of these strategies in China is still under intense debate and it seems that China is choosing to take a conservative approach by allowing some development in each area rather than choosing one particular option over all others.

In spite of these uncertainties, it is clear that China will need to make use of the expertise, experience, and resources of international actors to address domestic problems of energy consumption and carbon dioxide emissions, and as such there are a wide range of opportunities for international companies, governments, and organizations to provide consulting, research, financial and technical cooperation, support, and services to assist China develop sustainably.

## Sources

An, Feng (2006). *Chinese Transportation Markets and Policy in a High Oil Price Environment*. PowerPoint Presentation. Third Transatlantic Energy and Climate Change Workshop, March 30-31, 2006, Paris. Available at: [http://www.autoproject.org.cn/library\\_en.html](http://www.autoproject.org.cn/library_en.html).

An, Feng (2005). *China Experience with Fuel Efficiency Standards*. PowerPoint Presentation. US EPA 2005 Asia Pacific American Heritage Month Conference, May 31, 2005, Ann Arbor, MI. Available at: [http://www.autoproject.org.cn/library\\_en.html](http://www.autoproject.org.cn/library_en.html).

An, Feng and Sauer, Amanda (2004). *Comparison of Passenger Vehicle Fuel Economy and Greenhouse Gas Emission Standards around the World*. Prepared for the Pew Center on Global Climate Change. Available at: [http://www.pewclimate.org/global-warming-in-depth/all\\_reports/fuel\\_economy/index.cfm](http://www.pewclimate.org/global-warming-in-depth/all_reports/fuel_economy/index.cfm).

Asia Pacific Energy Research Centre (APEREC) (2004). *Energy in China: Transportation, Electric Power, and Fuel Markets*. Available at: <http://www.ieej.or.jp/aperc/publications.html>.

BP (2005). *BP Statistical Review of World Energy June 2005*. Available at: [www.bp.com/statisticalreview](http://www.bp.com/statisticalreview).

Cheng, Yang (2006). "Favorable Policies Encouraged." *China Daily*. June 19, 2006. Available at: [http://www.chinadaily.com.cn/bizchina/2006-06/19/content\\_620221.htm](http://www.chinadaily.com.cn/bizchina/2006-06/19/content_620221.htm).

China Automotive Technology Research Center (CATARC) and China Association of Automobile Manufacturers (CAAM) (2005). *2005 Automotive Industry of China*. 2005. Tianjin, China.

*China Daily* (2006). "Car Tax Raised to 20% to Spur Fuel Efficiency." March 22, 2006. Available at: [http://www.chinadaily.com.cn/china/2006-03/22/content\\_549350.htm](http://www.chinadaily.com.cn/china/2006-03/22/content_549350.htm).

Clean Air Initiative for Asian Cities (CAI) (2006). *Bus Rapid Transit (BRT) Overview*. Available at: <http://www.cleanairnet.org/caiasia/1412/article-59592.html>.

Congress of the United States Congressional Budget Office (CBO) (2006). *China's Growing Demand for Oil and Its Impact on U.S. Petroleum Markets*. Available at: <http://www.cbo.gov/showdoc.cfm?index=7128&sequence=0>.

Energy Information Administration (EIA) (2005). *International Energy Outlook 2005*. Available at: <http://www.eia.doe.gov/oiaf/ieo/>.

Energy Information Administration (2004). *Annual Energy Review 2004*. Available at: <http://www.eia.doe.gov/emeu/aer/>.

Energy Information Administration (2005). *China Country Analysis Brief*. Available at: <http://www.eia.doe.gov/emeu/cabs/china.html>.

Gesellschaft für Technische Zusammenarbeit (GTZ) (2006). *Liquid Biofuels for Transportation: Chinese Potential and Implications for Sustainable Agriculture and Energy in the 21st Century*. Commissioned by German Ministry for Food, Agriculture, and Consumer Protection (BMELV) through German Agency for Renewable Resources (FNR) (in press).

He, Dongquan, Program Officer, Transportation, the Energy Foundation's China Sustainable Energy Program. Interview May 31, 2006.

He, Kebin, et. al., (2005). Oil Consumption and CO2 Emissions in China's Road Transport: Current Status, Future Trends, and Policy Implications, *Energy Policy 33* (2005), 1499-1507, Elsevier publication.

- Ingram, G. K. (1998). Patterns of metropolitan development: What have we learned? *Urban Studies* 35(7):1019–1035.
- International Association of Public Transport European Union Committee (UITP-EU) (2006). *The Role of Public Transport to Reduce Green House Gas Emissions and Improve Energy Efficiency*. Available at: <http://www.uitp.com/eupolicy/publications.cfm>.
- International Energy Agency (IEA). *Hybrid Electric Vehicles*. Available at: <http://www.ieahev.org/hybrid.html>.
- International Energy Agency. *IEA Energy Statistics*. Available at: <http://www.iea.org/Textbase/stats/>.
- Luhnow, David, and Samor, Geraldo (2006). “As Brazil Fills Up on Ethanol, It Weans Off Energy Imports.” *The Wall Street Journal*. January 16, 2006. Available at: <http://yaleglobal.yale.edu/display.article?id=6817>.
- Ministry of Communications of the People’s Republic of China (MOC) (2004). *Transportation Overview*. (In Chinese.) Available at: <http://www.moc.gov.cn/gaikuang/>.
- Ministry of Finance of the People’s Republic of China (MOF) (2006). *Consumer Tax Survey*. (In Chinese.) Available at: [http://www.mof.gov.cn/news/20060323\\_2114\\_13944.htm](http://www.mof.gov.cn/news/20060323_2114_13944.htm).
- National Bureau of Statistics of China (NBS) (2005). *China Statistical Yearbook 2005*. Available at: <http://www.stats.gov.cn/tjsj/ndsj/2005/indexeh.htm>.
- National Development and Reform Commission (NDRC) (2004). *China Medium and Long Term Energy Conservation Plan*. Available at: [http://www.beconchina.org/energy\\_saving.htm](http://www.beconchina.org/energy_saving.htm).
- Niederburger, Anne, and Conrad Brunner (2006). *Swiss Energy Label for Passenger Vehicles*. Presented to Chinese State Environmental Protection Administration, February 8, 2006.
- Sperling, Daniel, Zhenhong Lin, and Peter Hamilton (2003), Rural Vehicles in China, Institute of Transportation Studies, University of California, Davis.
- The People’s Republic of China Initial National Communication on Climate Change*. (In Chinese). 2004. Beijing, China.
- Zhu, Songli, Associate Professor, Center for Energy, Environment and Climate Change, Energy Research Institute, NDRC. Interview June 9, 2006.
- Wen, Wendy (2006). *Biodiesel in China*. PowerPoint Presentation. Motor Vehicle Emission Control Workshop, May 10, 2006, Hong Kong. Available at: [http://www.cse.polyu.edu.hk/~activi/MoVE2006/pub\\_frame.htm](http://www.cse.polyu.edu.hk/~activi/MoVE2006/pub_frame.htm).
- World Resources Institute (WRI) (2005). *Growing in the Greenhouse: Policies and Measures for Sustainable Development while Protecting the Climate*. Available at: <http://pubs.wri.org/growingingreenhouse-pub-4087.html>.
- Wu, Wen Hua, Director, Senior Research, Division of Transportation Economics and Technology, Institute of Comprehensive Transportation, NDRC. Interview June 7, 2006.
- Xu, Zebin, Manager, Sustainable Mobility – China, BP. Interview June 6, 2006.